MCR-74-167 (Issue 1)

Phase II Quarterly Progress Report No. 1

March 1, 1974 through May 31, 1974

"Design, Fabrication, and Test of
Lightweight Shell Structure"

Contract NAS8-29979

Approved by:

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FOREWORD

This quarterly report was prepared and is submitted by the Denver Division of Martin Marietta Corporation in accordance with the requirements of Exhibit "A", Report Requirements of Contract NAS8-29979. This is an 18 month contract consisting of a 6 month Phase I and a 12 month Phase II. Phase I work was reported in Interim Report No. MCR-74-92, March, 1974. This quarterly report covers Phase II work performed during the period from March 1, 1974 to May 31, 1974. The program is sponsored by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama, with Mr. Carl Loy, the Contracting Officers' Representative (COR). The program is being performed by the Stress, Test, and Advanced Structures Section, Structures and Materials Department, Martin Marietta Corporation--Denver Division, with Mr. John R. Lager serving as Program Manager (PM).

The following Martin Marietta personnel have been principal contributors to the program: Joseph W. Maccalous and Bernard M. Burke, Composite Fabrication; Alan E. Muhl, Metal Fabrication; Arthur Feldman, Materials; Joseph M. Toth, Jr., Design and Analysis; and Major L. Sansam, Structural Test.

CONTENTS

I. INTRODUCTION AND SUMMARY

During Phase I of Contract NAS8-29979, Design, Fabrication, and Test of Lightweight Shell Structure, a cylindrical shell skirt structure 4.57 m (180 in.) in diameter and 3.66 m (144 in.) high was subjected to a design and analysis study using a wide variety of structural materials and concepts. The design loading of 1225.8 N/cm (700 lb/in.) axial compression and 245.2 N/cm (140 lb/in.) torsion is representative of that expected on a typical Space Tug skirt section. Structural concepts evaluated included honeycomb sandwich, truss, isogrid, and skin/stringer/frame. The materials considered included a wide variety of structural metals as well as glass, graphite, and boron-reinforced composites. The most unique characteristic of the candidate designs is that they involve the use of very thin-gage material. Fabrication and structural test of small panels and components representative of many of the candidate designs served to demonstrate proposed fabrication techniques and to verify design and analysis methods. Three of the designs evaluated, honeycomb sandwich with aluminum faceskins, honeycomb sandwich with graphite/epoxy faceskins, and aluminum truss with fiberglass meteoroid protection layers were selected for further evaluation. These concepts result in overall cylinder structural weight in the range 2.59 to 3.08 kg/m^2 (0.53 to 0.63 lb/ft^2).

This quarterly report covers the first three months effort under Phase II, Fabrication and Test. During this phase, three structural components of each of the three selected structural concepts will be fabricated. A development panel with approximately 1.83 m by 0.915 m (6 ft by 3 ft) overall dimensions will be fabricated for each structural concept. These panels will serve to verify fabrication techniques and will not be subjected to structural test. Successful fabrication of the development panels will be followed by fabrication of 1.83 m by 0.915 m (6 ft by 3 ft) compression panels which will be subjected to axial compression test loading. A 0.915 m by 0.915 m (3 ft by 3 ft) panel of each concept will also be fabricated and subjected to pure shear test loading. Progress during the first quarter of Phase II included, procurement of all materials required for Phase II, structural test plan issued, fabrication drawings completed, fabrication plan completed, fabrication of graphite/epoxy faceskins, chem mill of aluminum faceskins, chem mill of some aluminum truss components and fabrication of graphite/epoxy honeycomb sandwich 1.83 m by 0.915 m (6 ft by 3 ft) development panel.

II. PHASE II - FABRICATION AND TEST

Work during Phase II of contract NAS8-29979 involves verification of the predicted potential of three lightweight shell structural concepts designed and selected during Phase I. The aluminum honeycomb sandwich concept utilizes 0.025 cm (0.010 inch) thick 2014-T6 aluminum faceskins bonded to 1.51 cm (0.595 inch) thick 1/8-5052-0.0007-3.1 aluminum hexcel core using 0.0035 inch thick FM-24 film adhesive. The graphite/epoxy honeycomb sandwich concept uses identical core and adhesive but has 0.041 cm (0.016 inch) thick, six layer graphite/epoxy faceskins. The aluminum truss concept uses basic 3.81 cm by 2.86 cm (1 1/2 inch by 1 1/8 inch) 2024-T3 aluminum tubing with 0.125 cm (0.049 inch) wall thickness. These basic tubes are chem milled to different web and flange thicknesses for the individual truss components. The joint attachment is made using doubler plates mechanically fastened with CR-2251 6-2 bulbed cherrylock rivets. A 0.010 cm (0.004 inch) thick fiberglass sheet is bonded to the inner and outer surfaces of the truss to provide meteoroid protection.

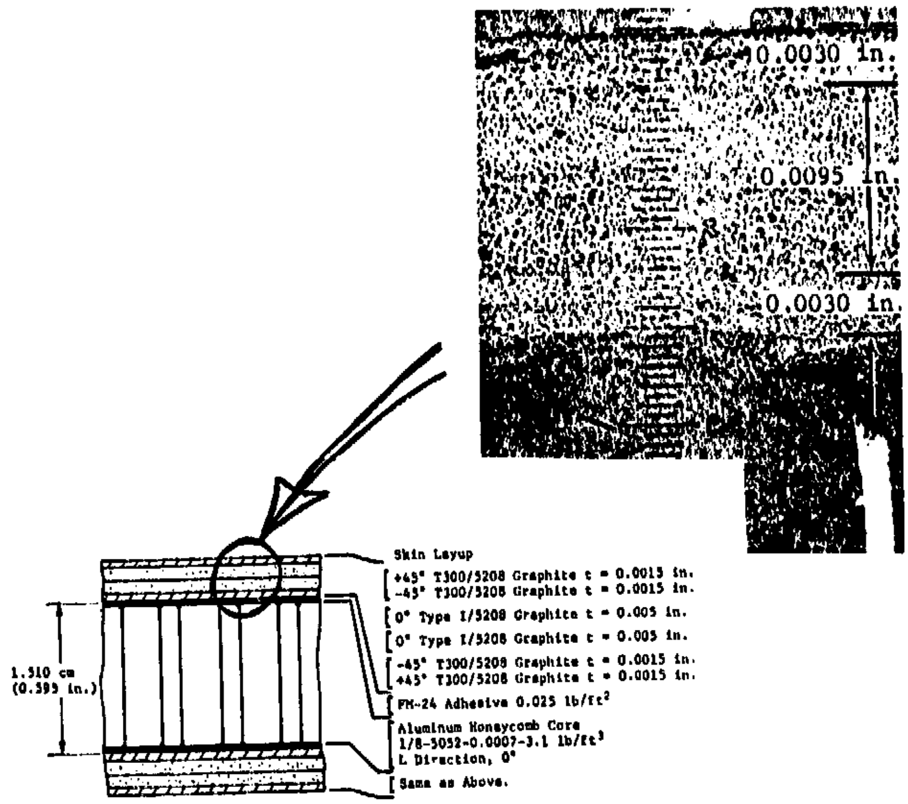
Three panels, a 1.83 m by 0.915 m (6 ft by 3 ft) development panel, a 1.83 m by 0.915 m (6 ft by 3 ft) compression test panel, and a 0.715 m by 0.915 m (3 ft by 3 ft) shear test panel will be fabricated for each of the three structural concepts. Successful test of these panels will help to verify the predicted potential of these lightweight shell concepts.

Design drawings of the panels to be fabricated during Phase II are included in Appendix A. These drawings will be updated in the event design changes are required due to unforseen manufacturing difficulties.

Phase II panel fabrication plans, listed in Appendix B, were developed based on experience gained during Phase I fabrication development work. The only expected added difficulty is related to the significantly larger size of Phase II panels.

A. <u>Graphite/Epoxy Honeycomb Sandwich Fabrication</u>

All of the graphite/epoxy faceskins required for the three sandwich panels have been fabricated. The basic layup of these faceskins is shown schematically and in a typical photomicrograph in figure 1. Layup of one of the skins during application of the fifth layer is shown in figure 2. Care must be taken during layup to make good splices between adjacent strips of prepreg in a particular layer. Some degree of overlapping or gapping is unavoidable, however, a method of precure compaction was developed during Phase II which eliminates perceivable seams or ridges in the cured faceskin.

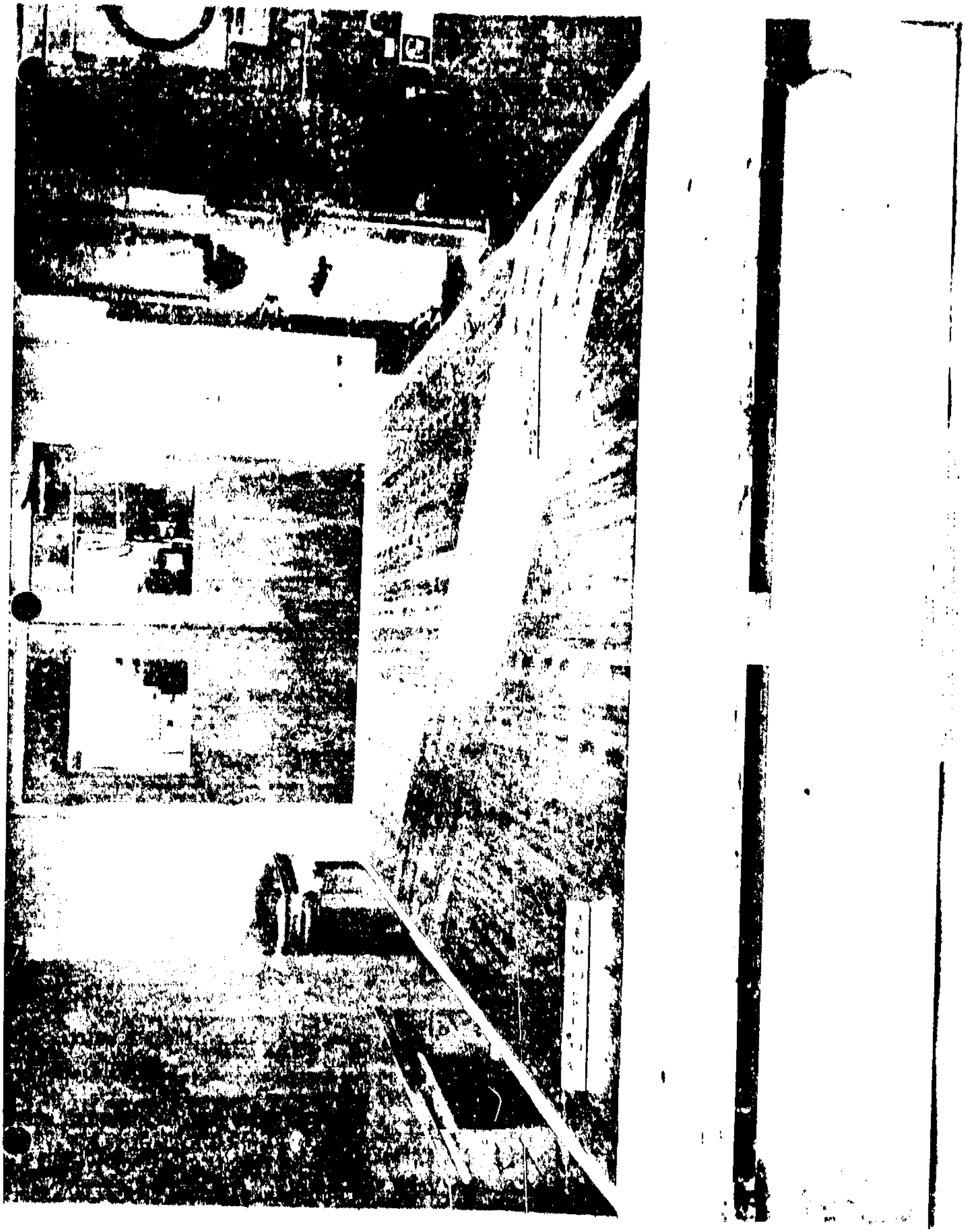


(h) Honeycomb Sandwich - Graphite/Epoxy Face Skins

Figure 1

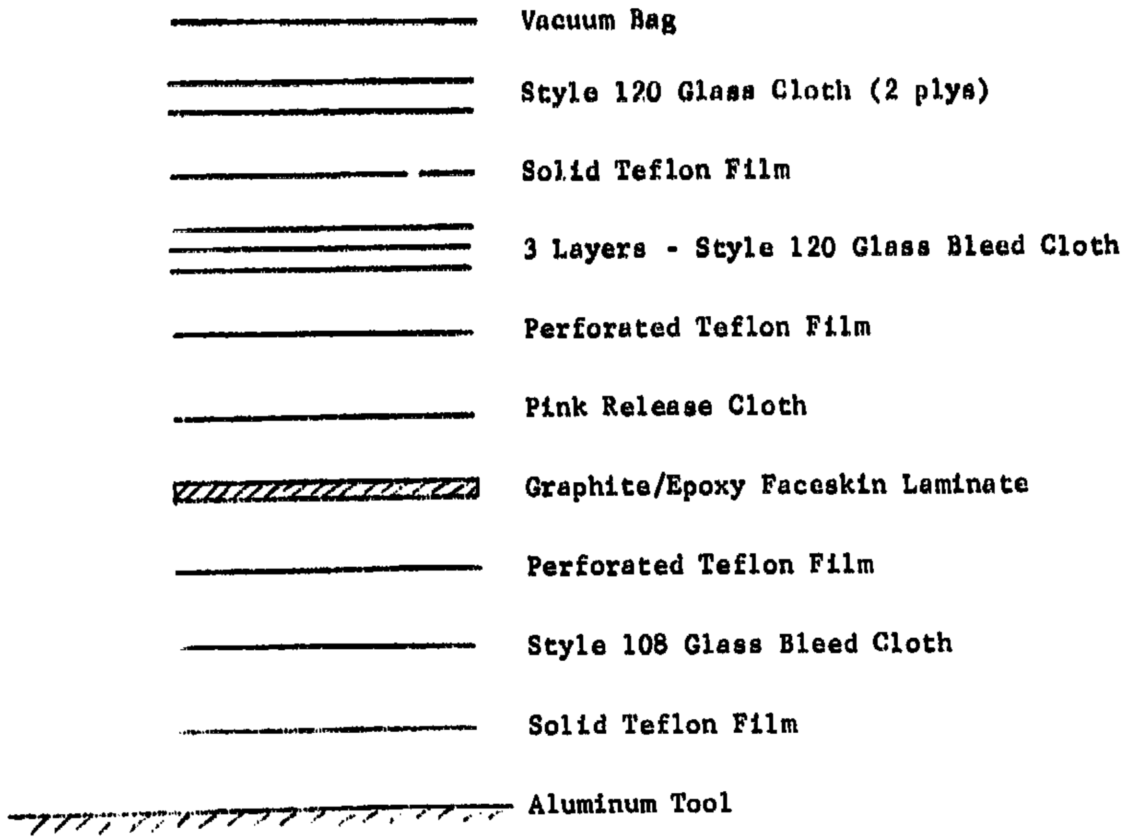
Graphite/Epoxy Panel Configuration

The vacuum bag system used for all graphite/epoxy faceskins is shown schematically in Figure 3. Again, this system was shown to be



Issue 1

Vacuum Bag System for Graphite/Epoxy Faceskins



<u>Process:</u>

1. Compaction Cycle
   a. Vacuum bag system shown above
   b. Full vacuum pressure
   c. Heat to 180°F in 45 min.
   d. Hold at 180°F for 10 min.
   e. Remove from autoclave and hand roll
      (Note: Do not remove bag system)

2. Cure Cycle
   a. After compaction, with same bag system, place in autoclave
   b. Cure per NARMCO 5208 cure cycle

Figure 3
Graphite/Epoxy Faceskins
Vacuum Bag System

satisfactory during Phase I development work. Prior to cure, the fully bagged part was heated in the autoclave to 180°F in 45 minutes, held for 10 minutes and immediately removed from the autoclave. The heated layup was then compacted with teflon paddles as shown in Figure 4 to remove ridges and irregularities caused during layup. The compacted part was then placed back in the autoclave and cured using the Narmco 5208 cure cycle. The desired and actual cure history of one of the graphite/epoxy faceskins is shown in Figure 5. A fully cured faceskin is shown in Figure 6. Pertinent data about the five fabricated graphite/epoxy faceskins are listed in Table 1. The average thickness of the five sheets is slightly higher than hoped for due to proportionally smaller edge resin bleed for the larger laminates.

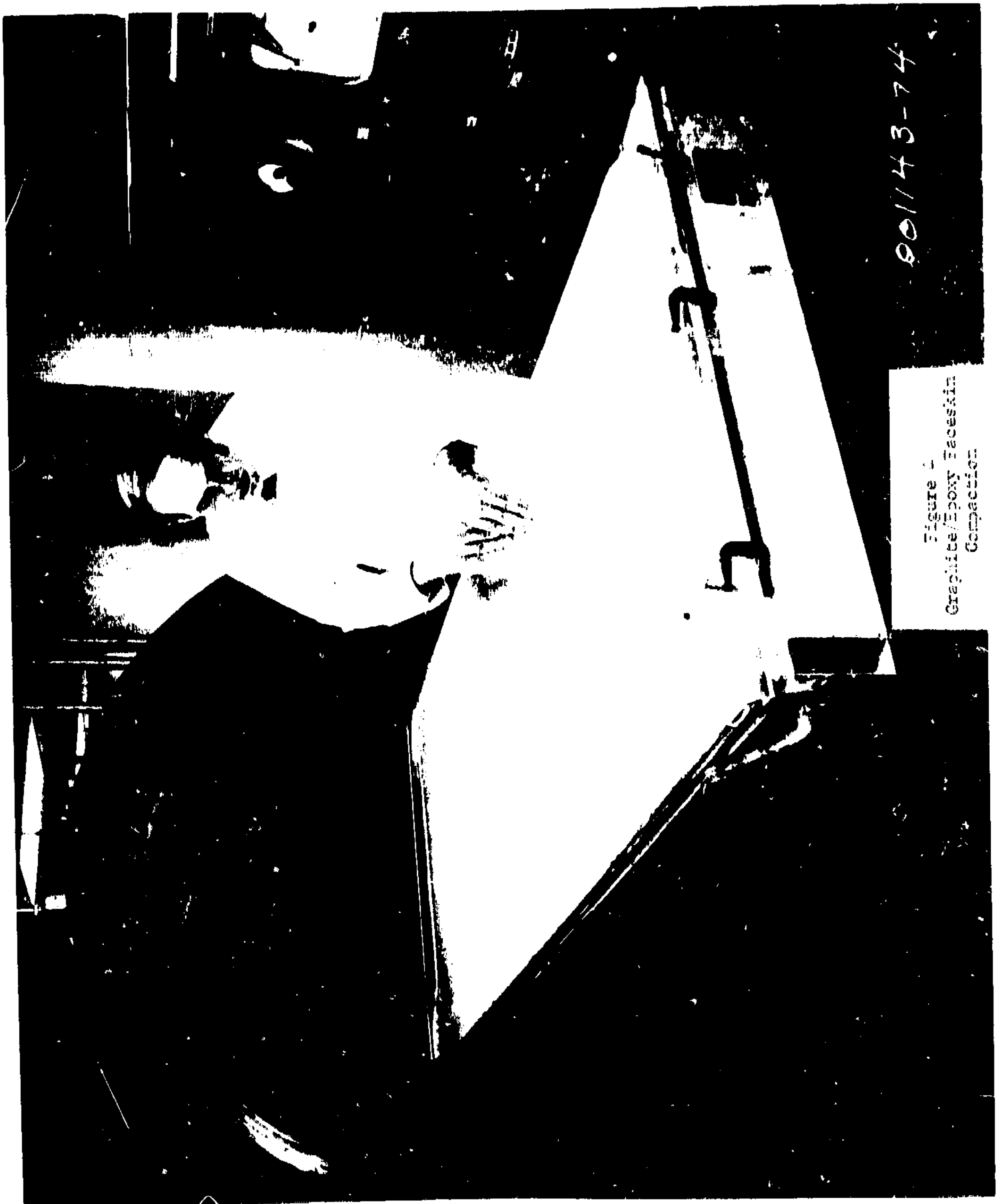


Figure 4
Graphite/Epoxy Faceskin
Compaction

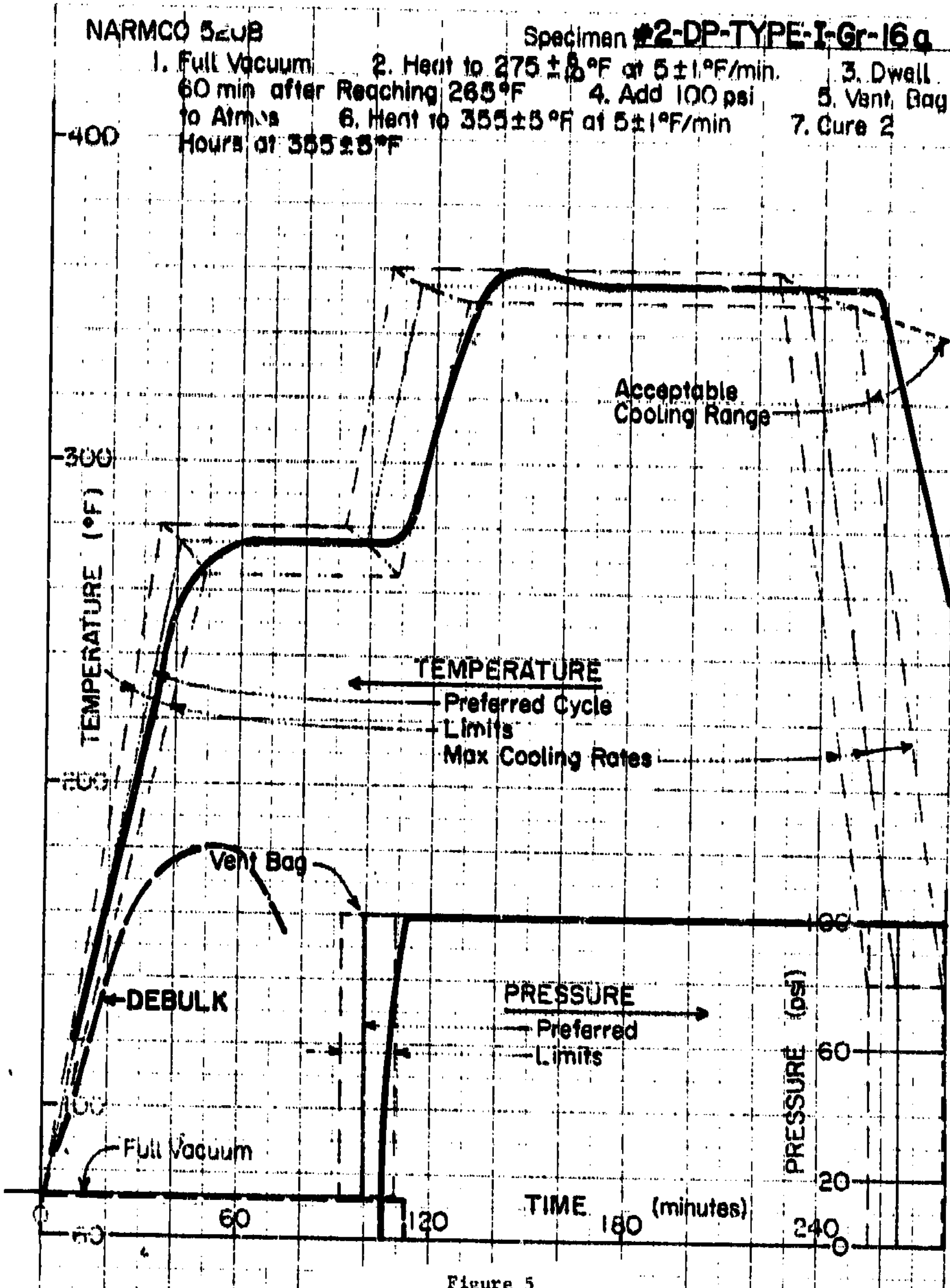


Figure 5
Graphite/Epoxy Faceskin
Cure Cycle

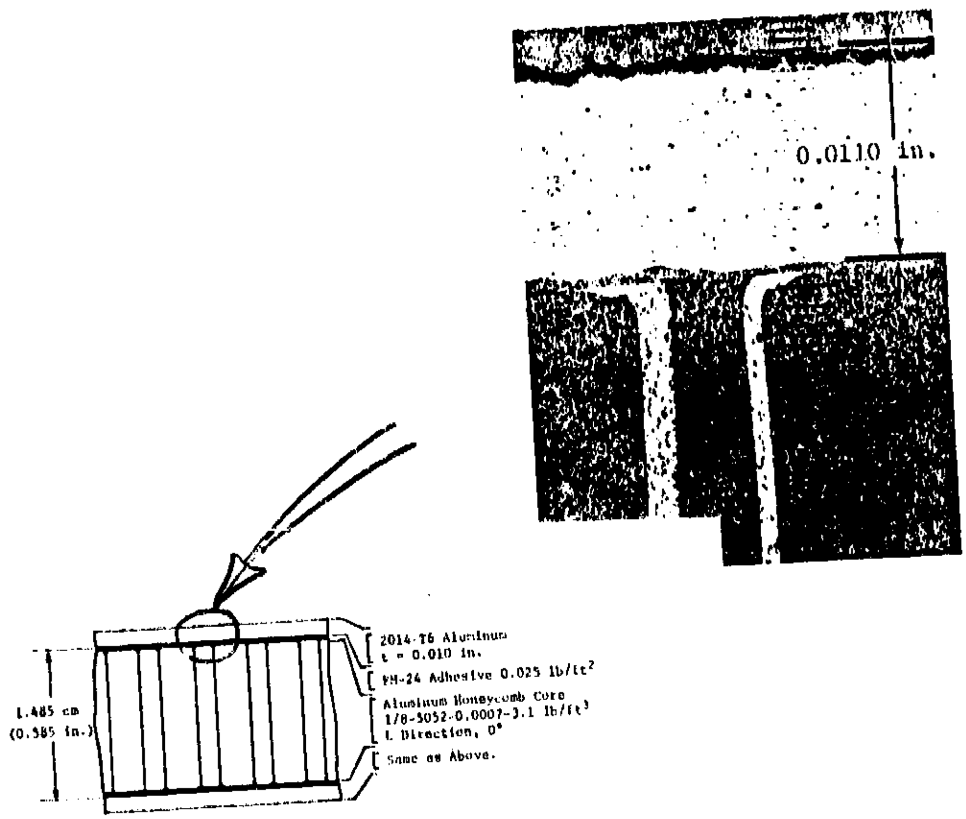
Table 1

Graphite/Epoxy Faceskins

Faceskin Laminate Designation	Length Inches (Cm.)	Width Inches (Cm.)	Weight, Lb. (Kg.)	Average Thickness Inches (Cm.)
DP-Type I-Gr-16a	73.88 (187.50)	36.37 (92.30)	—	0.018 (0.046)
DP-Type I-Gr-16B	73.88 (187.50)	36.37 (92.30)	—	[illegible] (0.046)
CP-Type I-Gr-16a	73.88 (187.50	36.37 (92.30)	2.70 (1.226)	0.018 (0.046)
CP-Type I-Gr-16b	73.88 (187.50	36.37 (92.30)	2.78 (1.260)	0.018 (0.046)
SP-Type I-Gr-16	73.77 (187.40)	36.34 (92.40)	2.26 (1.025)	0.015 (0.038)

B. Aluminum Honeycomb Sandwich Fabrication

The basic panel configuration for the aluminum honeycomb concept and a typical photomicrograph of a .028 cm (0.011 inch) thick faceskin bonded to aluminum hexcel core is shown in Figure 7. All of the faceskins for the aluminum honeycomb sandwich panels were fabricated during this quarter by chemically milling 0.101 cm (0.040 inch) thick 2019-T6 aluminum sheet down to 0.025 cm (0.010 inches) with a tolerance of -0.000 cm. and +0.005 cm. (+0.002 inches) on the finished thickness. Thickness data and comments on the seven 1.83 m by 0.915 m (6 ft. by 3 ft.) aluminum sheets which were chemically milled are listed in Table 2. Faceskins numbered 2 and 3 will be used to fabricate the 1.83 m by 0.915 m (6 ft. by 3 ft.) development panel. These sheets are slightly



(a) Honeycomb Sandwich - Aluminum Face Skins

Figure 7
Aluminum Panel Configuration

TABLE 2

ALUMINUM FACESKINS

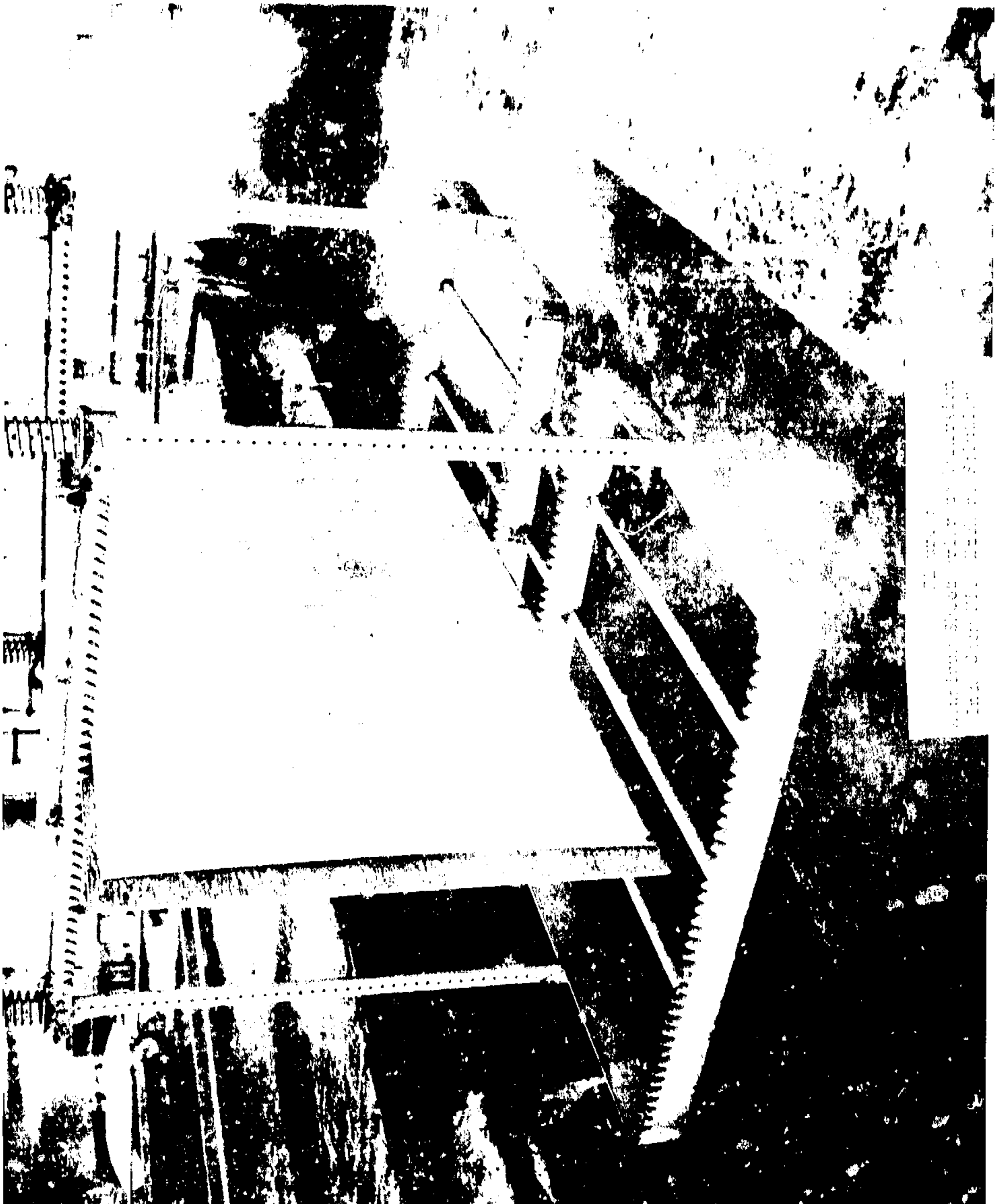
Sheet Number	Minimum Thickness, Inches (cm.)	Maximum Thickness, Inches (cm.)	Average Thickness, Inches (cm.)	Comments
1	0.0105 (0.0267)	0.0119 (0.0302)	0.0112 (0.0284)	Good
2	0.0115 (0.0292)	0.0134 (0.0340)	0.0121 (0.0307)	Slightly Thick
3	0.0112 (0.0284)	0.0132 (0.0335)	0.0121 (0.0307)	Slightly Thick
4	0.0106 (0.0269)	0.0118 (0.0300)	0.0114 (0.0290)	Good
5	0.0109 (0.0277	0.0121 (0.0307)	0.0114 (0.0290)	Good
6	0.0098 (0.0249)	0.0115 (0.0302)	0.0110 (0.0279)	One small Wrinkle
7	0.0101 (0.0256)	0.0120 (0.0305)	0.0111 (0.0282)	Two small Wrinkles

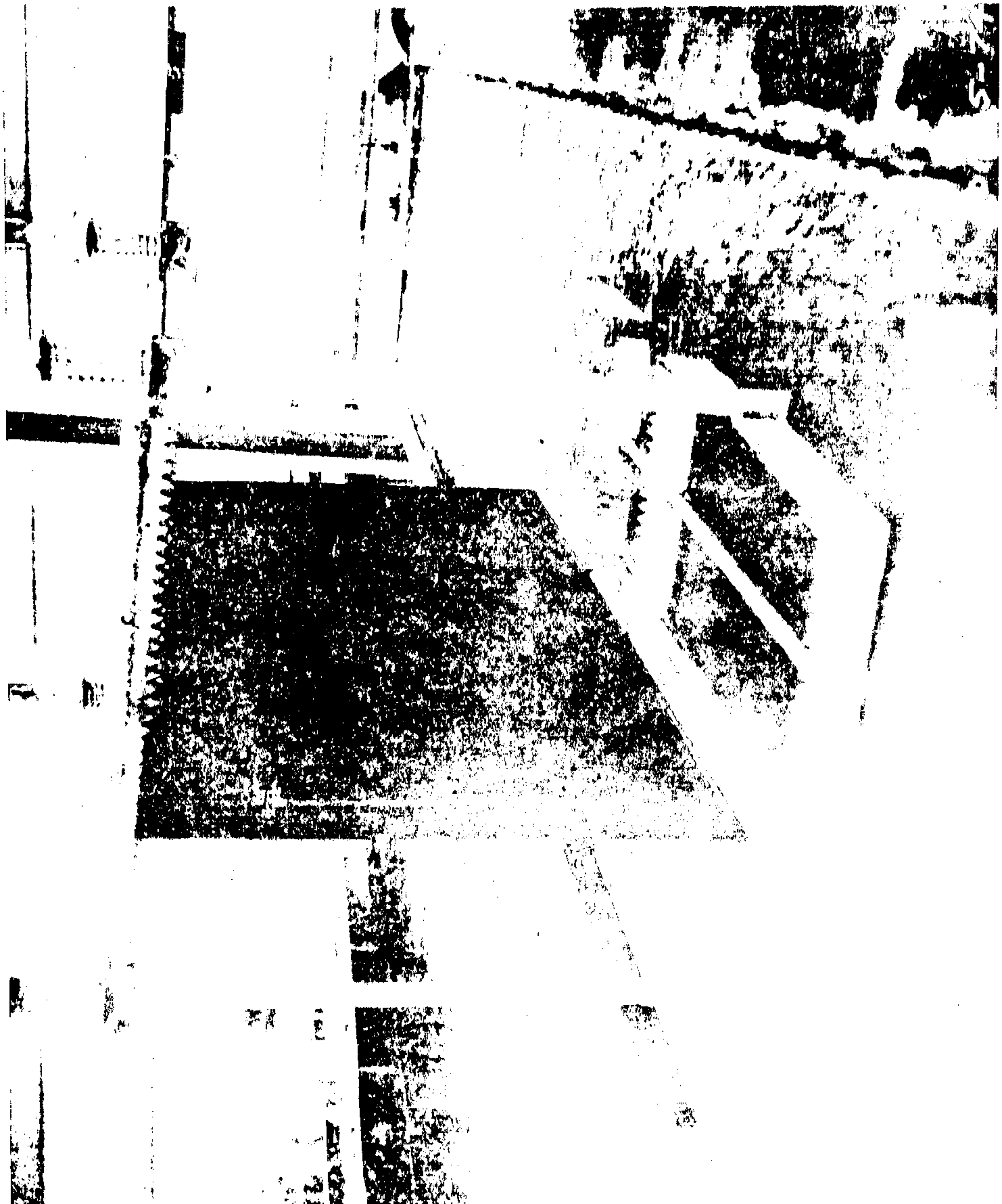
thicker than originally desired. Experience gained in chemically milling these sheets resulted in the development of techniques required to be able to meet thickness tolerances. Faceskins numbered 4 and 5 with average thickness of 0.0290 cm (0.0114 in) will be used to fabricate the (6 ft by 3 ft) panel for compression testing and number 1, with average thickness of 0.0284 cm (0.0112 inches) will be used to make the 0.915 m by 0.915 m (3 ft by 3 ft) shear test panel.

The step by step fabrication process used to chemically mill the aluminum sheets is listed in Appendix B - Manufacturing Processes. A typical panel just prior to being immersed in the etchant solution is shown in Figure 8 and same panel immediately after removal is shown in Figure 9.

Chemically milling large aluminum sheets to thin (0.010 inch) gage with reasonable finished thickness tolerance and surface quality requires that the starting blank be free of surface irregularities and have uniform thickness. The thickness tolerance on the 0.101 cm (0.040 inch) 2014-T6 aluminum sheets used was approximately ±0.0013 cm (±0.0005) inches) and the chem milled sheets had a tolerance of ± 0.002 cm (±0.001 inches). Thickness variation caused by chem milling is associated with etchant being in contact with the bottom portion longer than the top portion during dipping and removal operations. This effect is minimized by rotating the part after each material removal operation.

The thin aluminum sheets are very flexible and, therefore, were attached to a plywood board during the chem mill operation. The sheet is chem milled from one side with the side adjacent to the plywood board masked off to prevent etchant attack. Removing material from one rather than both sides results in better thickness control, however, it does cause some curvature of the finished skin due to release of residue stress. This curvature is not structurally degrading since it requires very little force to flatten the sheets.





C. Aluminum Truss Configuration

The aluminum truss configuration shown in Figure 10 contains tubular aluminum truss members mechanically fastened at the joints using doubler plates and blind cherry rivet fasteners. The inner and outer surfaces of the truss will be covered with thin (0.010 cm) fiberglass cloth sheets to provide meteoroid protection. The flanges and webs of the truss horizontal and diagonal members will be chemically milled to final dimensions.

The three panels, development, compression and shear, shown in Appendix A drawings are in the process of being fabricated. The general manufacturing workflow plan for these panels is shown in Figure 11. The process plan to be used is given in Appendix B. Two truss components, a horizontal and a diagonal member, have been chem milled to verify the proposed process prior to initiation of large panel fabrication. The tubes were plugged at both ends, one end with a vent tube, and masked for the chem milling operation. The maskant was first pealed off of the opposing sides to be chem milled to the smallest thickness. These sides were milled until the same thickness of material remained to be chem milled off of all four sides. The remaining two sides were stripped of maskant and chem milled to final thickness. Dimensional tolerance on this thickness was held within the 0.005 cm (0.002 in.) range desired.

All of the truss tube details and doubler plates for the three panels have been cut to size. The tube details are being prepared for chem milling.

The tool for assembling each truss has been started. The vertical tube members of each truss will be used for aligning the remaining truss members. Each vertical tube will be positioned by pins in the tool. (The tool is essentially a large flat steel table). Horizontal and diagonal members will be fitted to the tool and then rivet holes drilled into the tubes using the doubler sheets as guides.

The development and compression test panels will use spot welding at the top and bottom joints as indicated on the fabrication drawings of Appendix A. To verify the proposed welding techniques, doubler plates were welded to the top and bottom flanges of a tube section. A copper mandrel was placed inside the tubing for current flow and the top and bottom spot welds were made simultaneously. This was also accomplished using weld-bonding in which an adhesive is added at the interfaces prior to spot welding.

To determine the strength of the spot welds, test samples were welded and tested in axial tension. A single spot weld had an ultimate strength of 2920 N (650 lbs) per spot while a weld-bonded spot with one square inch bond area failed at a load of 9870 N (2200 pounds).

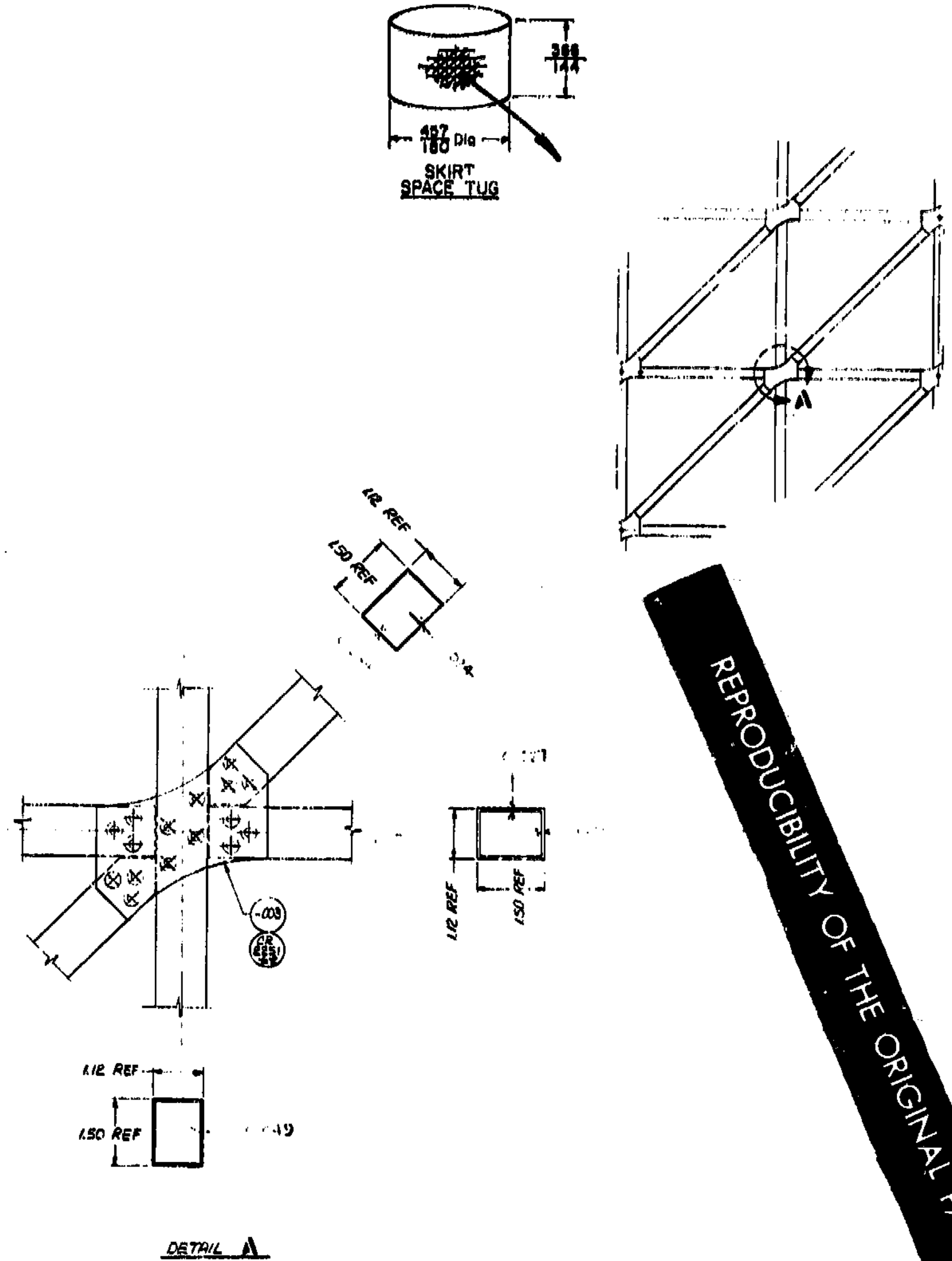


Figure 10. Aluminum Truss Configuration

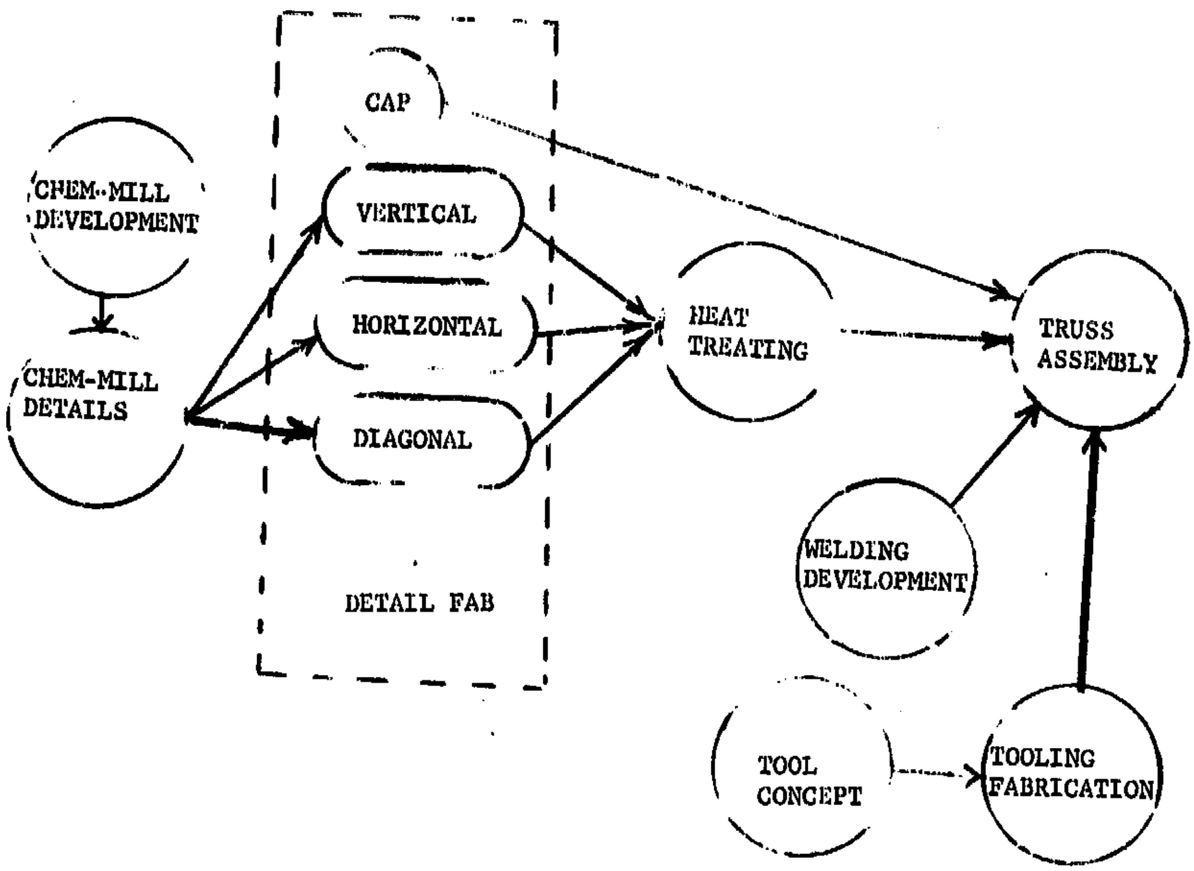


Figure 11. Aluminum Truss Configuration Manufacturing Workflow

D. Structural Test Plan

1. Introduction

During Phase I of NASA Contract NAS8-29979, "Design, Fabrication and Test of Lightweight Shell Structures," a cylindrical shell representative of Space Tug body structure was designed using a wide variety of structural concepts and materials. Eleven (11) of the designs were selected as being feasible candidates and of these, nine (1) were subjected to further evaluation through fabrication and test of small development panels. Results of the Phase I study are given in an Interim Report, number MCR-74-92. Three (3) of the designs evaluated, honeycomb sandwich with aluminum faceskins, honeycomb sandwich with graphite/epoxy faceskins and aluminum truss with fiberglass meteoroid protection layers were selected for further evaluation. This test plan defines structural tests to be performed on development test panels from each of the three structural concepts.

2. Purpose of Tests

The purpose of these tests is to verify predicted strength and stiffness of the selected Phase I structural concepts. Results of the tests will be used in selecting the most feasible structural concept for Space Tug body structure.

3. Description of Test Specimens

The test specimens consist of three compression panels approximately 1.83 m by 0.915 m (6 ft by 3 ft) and three shear panels approximately 0.915 m by 0.915 m (3 ft. by 3 ft.) one of each type from each of the three different structural concepts.

The honeycomb sandwich concept with aluminum faceskins, shown in Appendix A, consists of 1.51 cm (0.595 inches) thick lightweight 1/8-5052 0.0007-3.1 aluminum hexcel core with 0.025 cm (0.010 inch) thick 2024-T6 aluminum faceskins. Load introduction capability is provided by bonded on fiberglass end and edge tabs as shown.

The honeycomb sandwich concept with graphite/epoxy faceskins, shown in Appendix A, has a sandwich core identical to that used for the aluminum panels and all graphite/epoxy faceskins. These faceskins consist of four (4) ±45° layers of thin (0.0038 cm thick) T-300 graphite/Narmco 5208 epoxy material and 0.025 cm (0.010 inches) of 0° HM graphite/Narmco 5208 epoxy. Again, fiberglass tabs are provided for load introduction. The faceskin/core bond on all of the honeycomb sandwich panels is accomplished with thin (0.0089 cm thick) FM-24 adhesive film.

The aluminum truss concept shown in Appendix A, is built up of 2.86 cm by 3.21 cm (1 1/8 inch by 1 1/2 inch) thin 2024-T81 aluminum tubes fastened together at the joints with the aid of doubler plates and CR-2251-6-2 aluminum blind cherry rivets. The inside and outside truss surfaces are covered with bonded on thin (0.010 cm thick)

fiberglass/epoxy sheets for meteoroid protection. Load introduction capability is provided at appropriate truss joints by thickened aluminum regions to receive 0.95 cm (3/8 inch) diameter test bolts.

4. Test Loads

The design ultimate loads the expected maximum test loads and associated deflections for the test panels are listed in Table 3. Load application shall be in increments of 10 percent of design ultimate load until 90 percent of design ultimate is reached and in 5 per cent increments thereafter until failure. Test data shall be recorded at the end of each additional increment of loading.

5. Method of Test

a. Compression Panels

A schematic diagram of the test setup for the two honeycomb sandwich compression test panels is shown in Figure 11. Uniformly distributed axial compressive load shall be introduced into the test panel through bolted on aluminum test angles. The test specimens have bonded on fiberglass end reinforcement for distribution of test loads. The sides of the test panels shall be supported during test as shown in Figure 11. Side support angles shall prevent or resist motion normal to the panel surface and rotations at the sides, however, the panel shall be free to move vertically.

The test setup for the aluminum truss compression specimen, shown schematically in Figure 12, shall provide for application of equal axial compressive load at the ends of each axial stringer. Doublers at the ends of each stringer provide means for mechanically attaching test load introduction angles. The sides of the test panel shall be supported at truss joints such that motion normal to the plane of the panel and joint rotation is resisted. The side support shall, however, permit free vertical motion of the side stringers.

b. Shear Panels

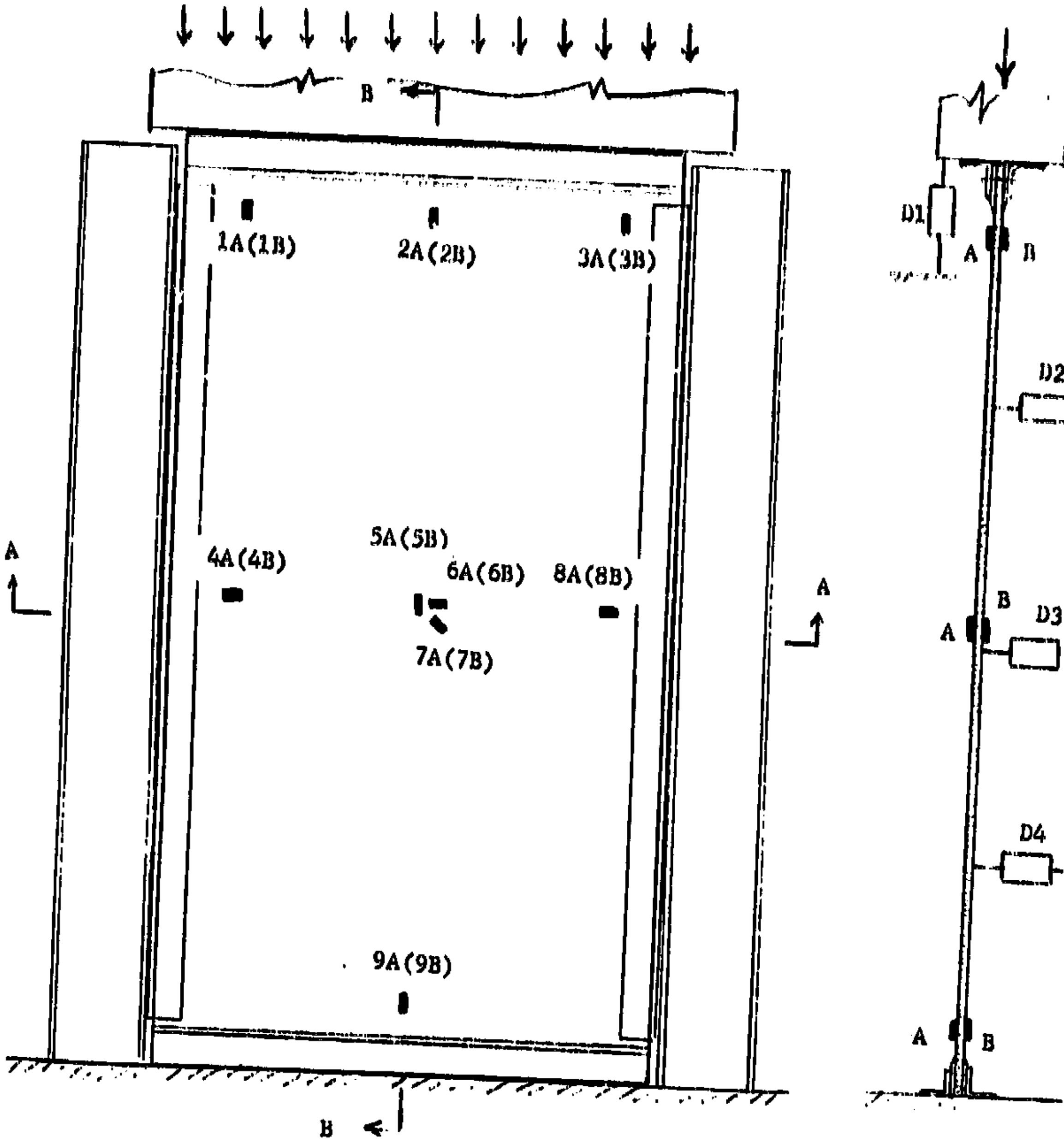
Uniformly distributed edge shear load shall be applied to the honeycomb sandwich shear test panels through a rigid "picture frame" apparatus as shown in Figure 13. The test panels are provided with fiberglass edge reinforcement for mechanical attachment of the loading frame. The unloaded corners of the test panels shall be supported such that deflection normal to the surface of the test panel is resisted.

The test setup for test of the truss shear panel is shown schematically in Figure 14. Equal axial tensile loads shall be applied at the truss joints as shown through a single 0.95 cm (3/8 inch) diameter hole through the reinforced joint regions. The unloaded truss corners shall be supported in an manner similer to that used for the honeycomb sandwich shear panels.

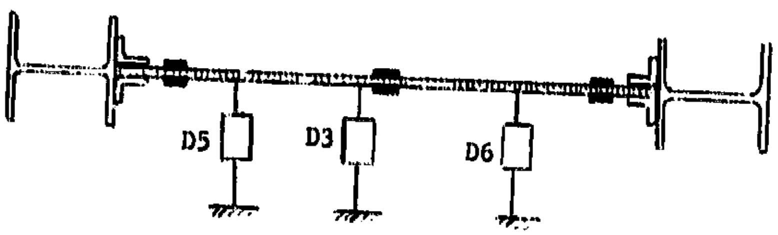
6. Instrumentation

TABLE 3 LOADS AND DEFLECTIONS

Panel Concept	Compression Panels: Design Ultimate Load, lb (N)	Compression Panels: Possible Maximum Failure Load, lb (N)	Compression Panels: Expected Axial Deflection at Design Ultimate, in. (cm)	Shear Panels: Design Ultimate Load, lb (N)	Shear Panels: Possible Maximum Failure Load, lb (N)	Shear Panels: Expected Diagonal Defl @ Design Ultimate, in. (cm)
Honeycomb - Aluminum Faceskin	25,200 (113,000)	28,700 (129,000)	0.25 (0.63)	7,130 (32,000)	38,800 (174,000)	0.043 (0.109)
Honeycomb - Graphite/ Epoxy Faceskins	25,200 (113,000)	45,000 (202,000)	0.10 (0.25)	7,130 (32,000)	13,760 (61,800)	0.045 (0.114)
Aluminum - Fiberglass Truss	37,000 (166,000)	42,900 (192,500)	0.34 (0.86)	19,500 (87,600)	29,300 (131,500)	0.100 (0.254)



Section B-B



SECTION A-A

Figure 11
Instrumentation
Honeycomb Sandwich Compression Panels
CP-Alum-10 and CP-Type I-Gr-15

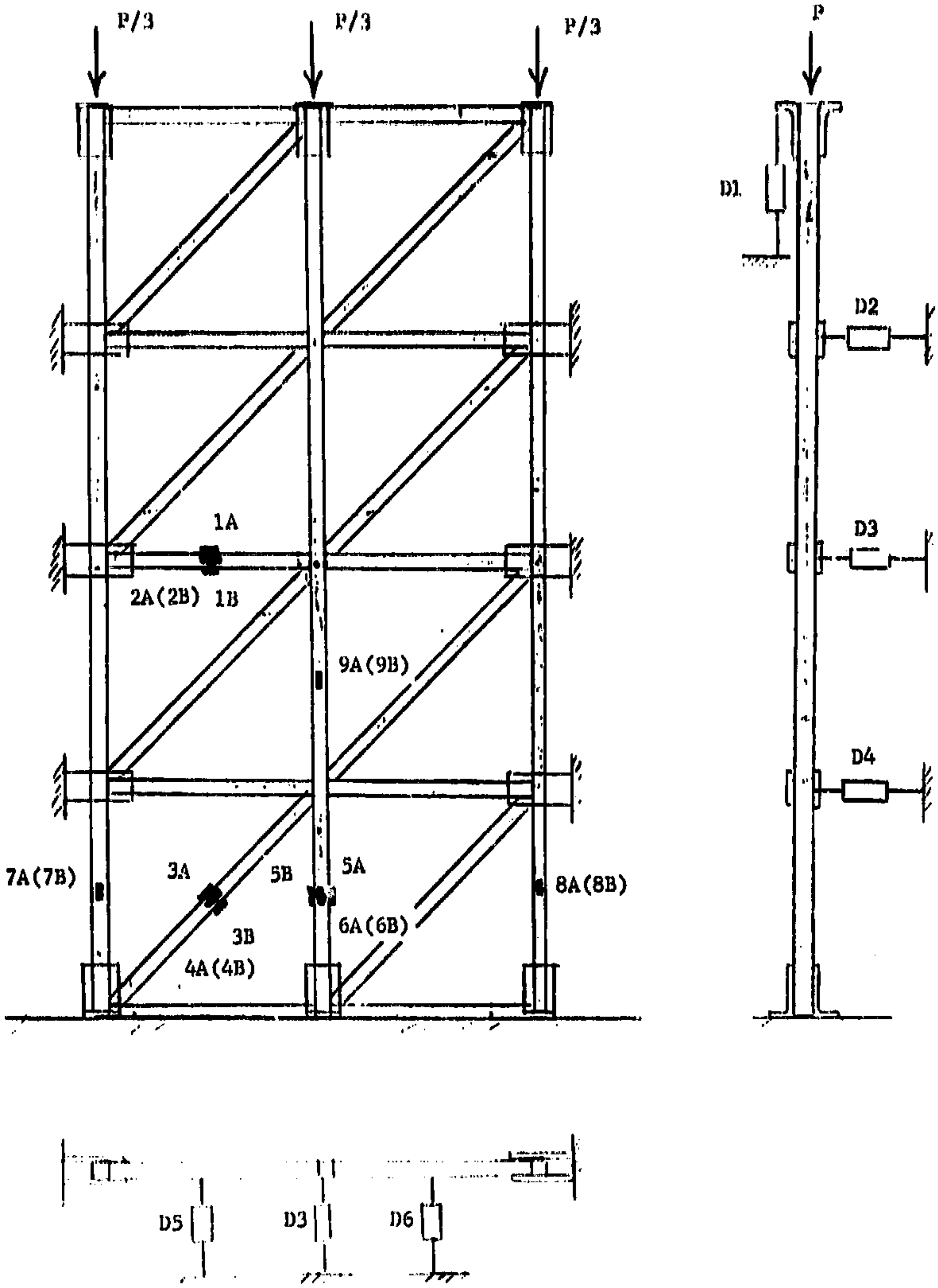
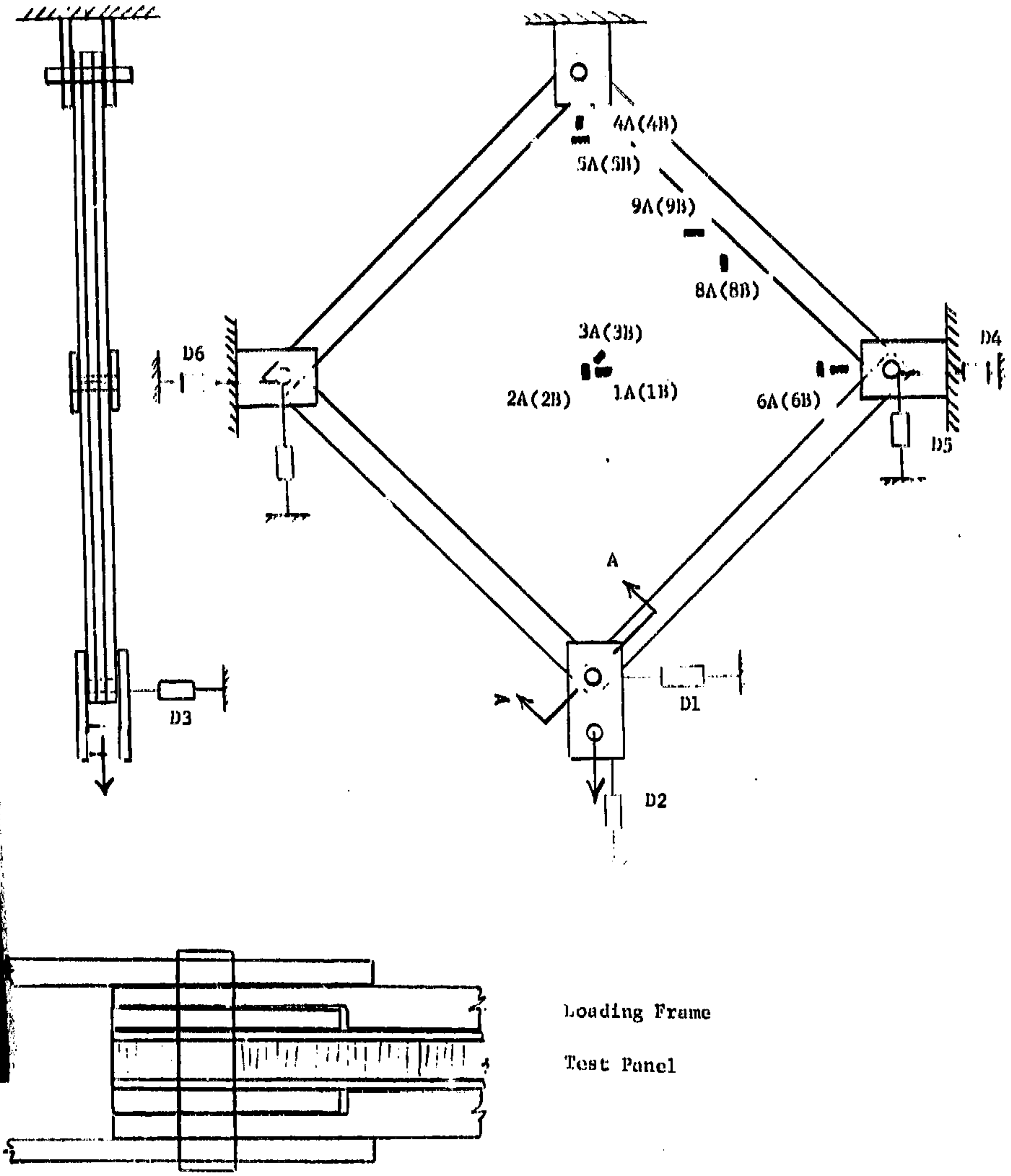


Figure 12
Instrumentation
Aluminum Truss Compression Specimen
CP-Alum Truss



Section A-A

Figure 13
Instrumentation
Honeycomb Sandwich Shear Panels
SP-Alum-10 and SP-Type I-Gr-15

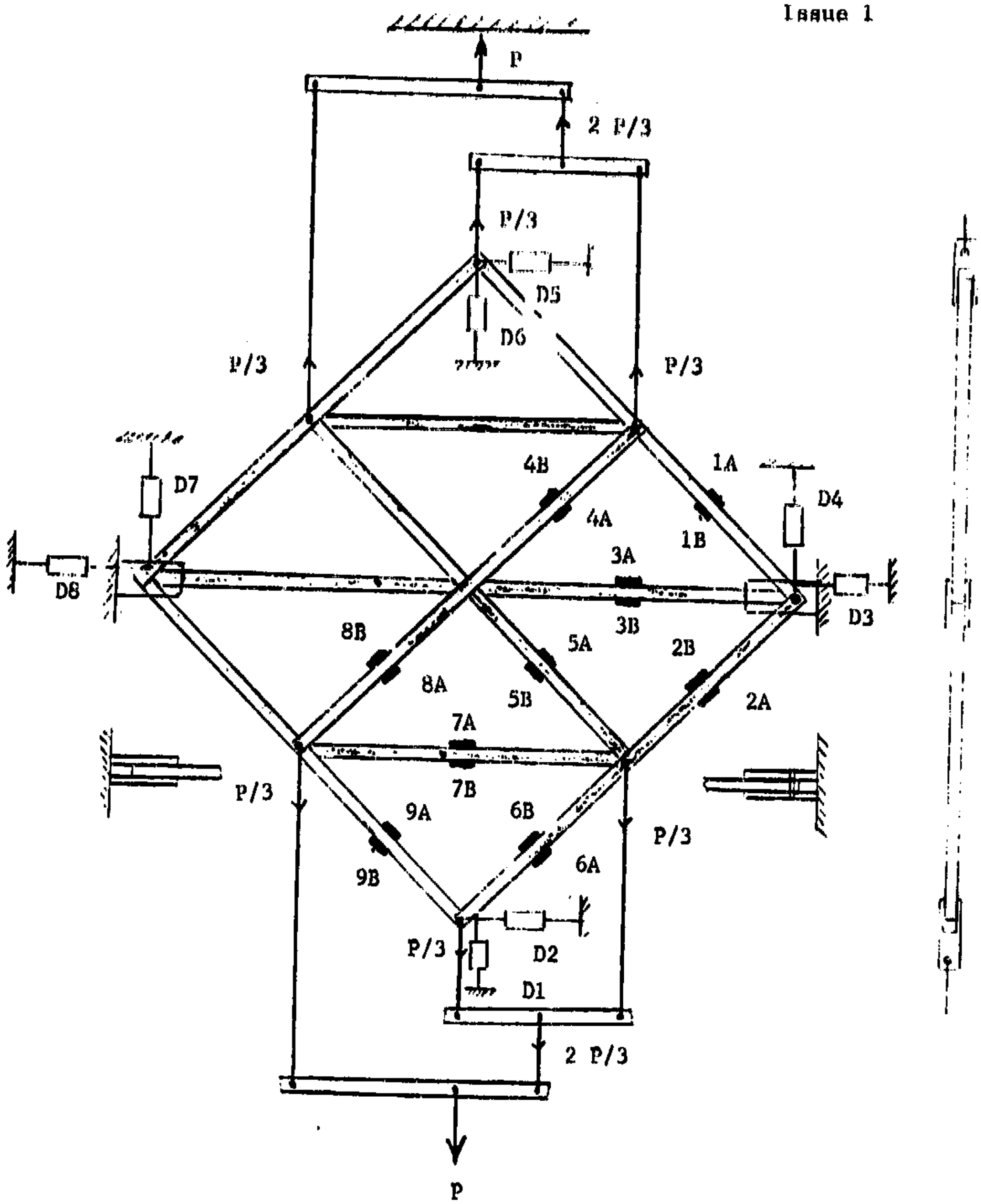


Figure 14
Instrumentation
Aluminum Truss Shear Specimen
SP-Alum Truss

Material strains during test shall be monitored using eighteen (18) strain gages per test panel located as shown in Figures 11-14 Strains shall be recorded at the end of each added increment of loading. Linear motion of points on the test panels shall be measured using linear motion transducers located as shown in Figure 11-14. The test panels use six (6) linear motion transducers each.

7. Test Monitoring and Inspection

Photos shall be taken of the untested panels, the test setup prior to test and the failed panels. Anomolies in the test panels prior to test shall be fully documented photographically and in writing.

8. Test Report Requirements

Copies of the raw test data shall be provided to the program manager the day following completion of each test. A formal test report including photos and plotted data shall be written by the test engineer following completion of the total test program.

III. Schedule and Plan for Future Work

The program master schedule indicating the portion of work completed is shown in Figure 15.

The following work is planned for the second quarter of Phase II:

1. Complete fabrication of all panels.
2. Complete structural test of honeycomb sandwich panels.
3. Ultrasonic inspection of honeycomb sandwich development panels.

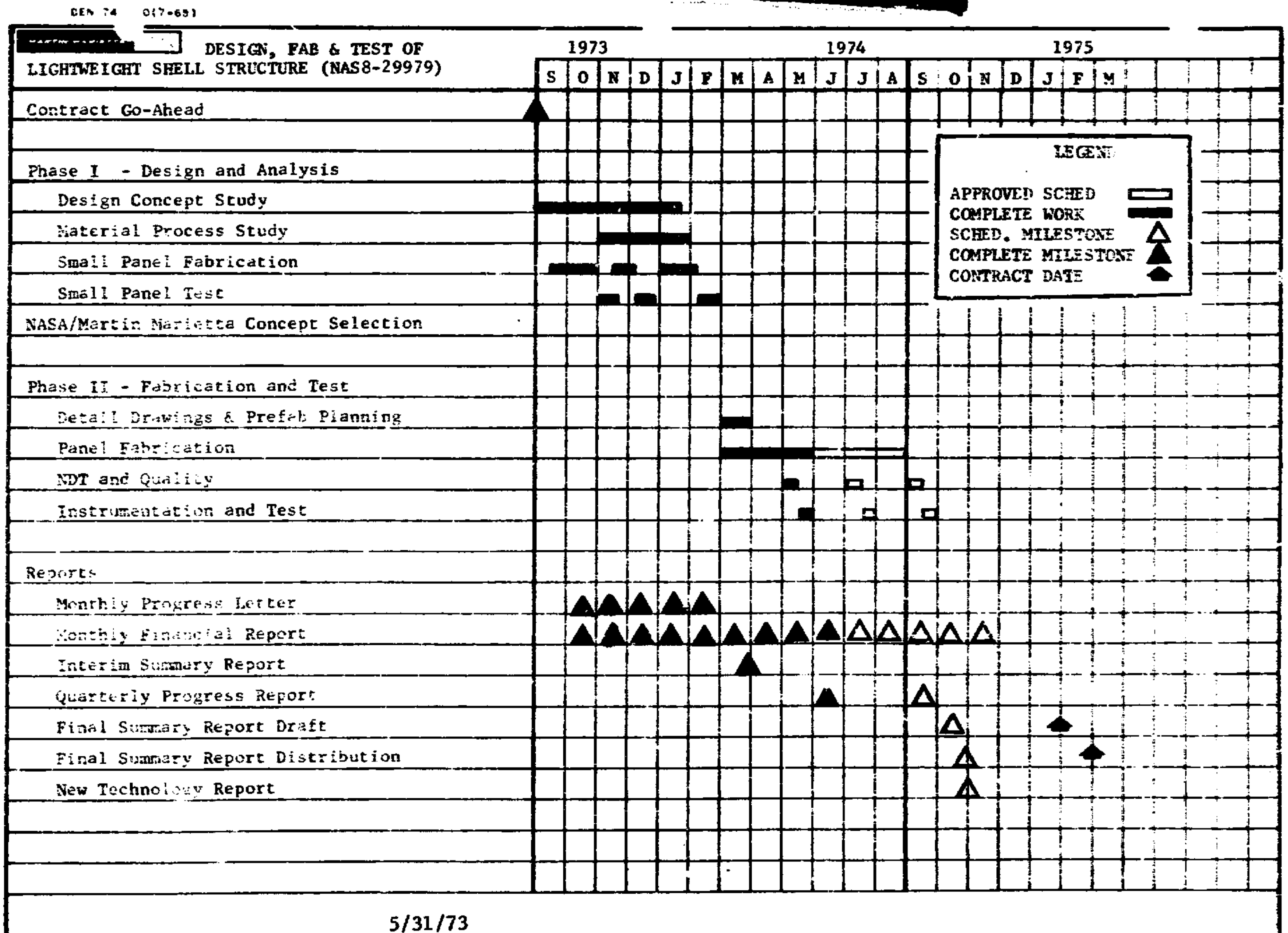


Figure 15 Program Master Schedule

Appendix A

Fabrication Drawings

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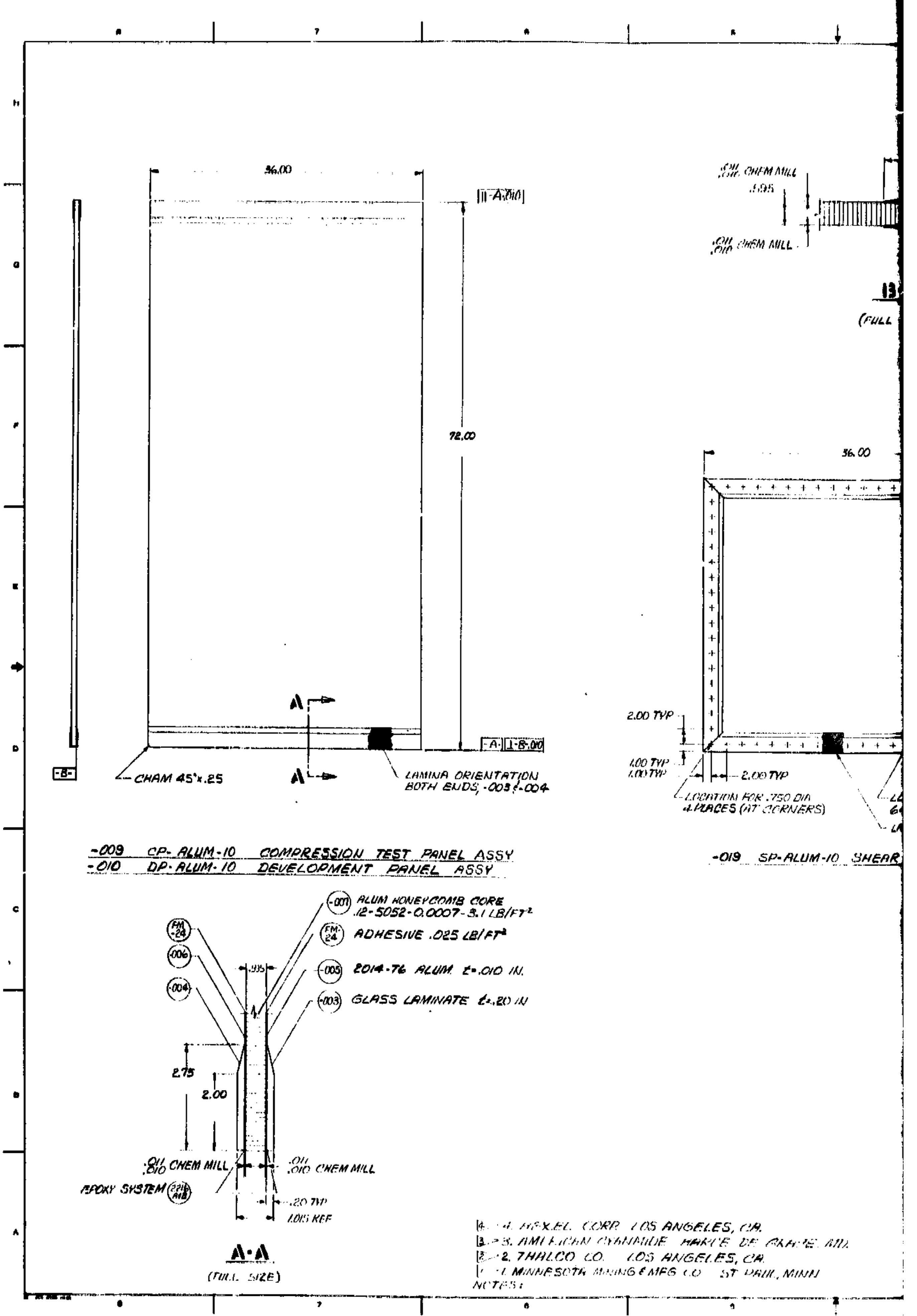

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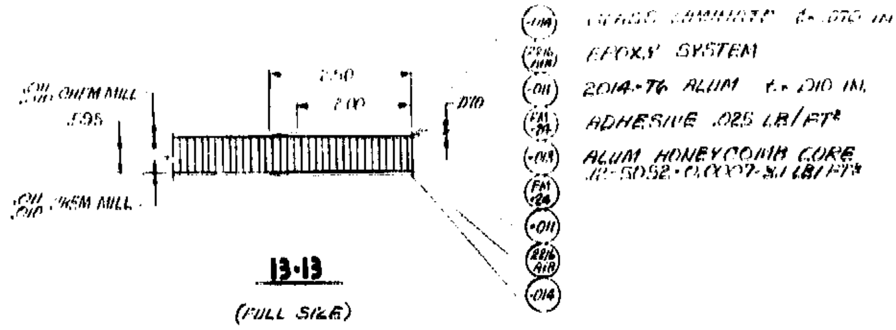
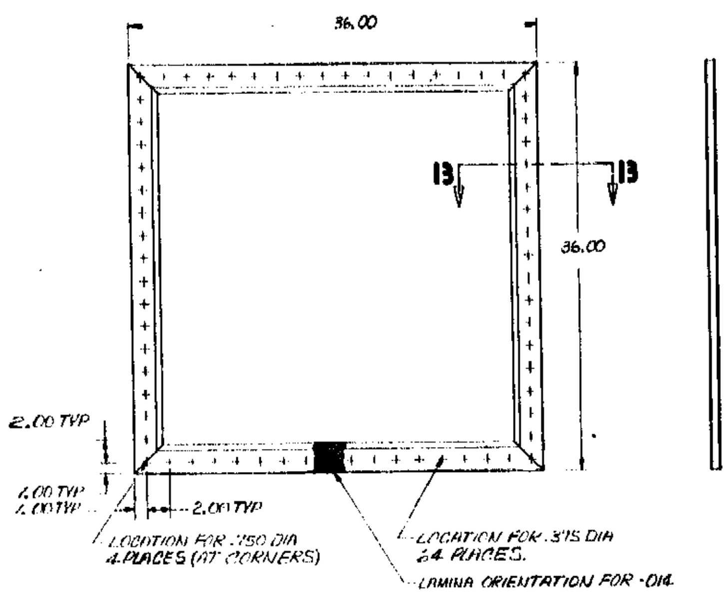


13-13
(FULL SIZE)



-019 SP-ALUM-10 SHEAR TEST PANEL ASSY

			2216 A/B	EPOXY SYSTEM		
			FM-24	ADHESIVE	.025 LB/FT²	
8			-014	STRIP	.070 x 5.00 x 37.00	GLASS LAMINATE - EPOXY
1			-013	CORE	.595 x 36.50 x 36.50	5052-0 AL .125-.0007-3.1 #/FT³ HONEYCOMB
1			-012	FACE	.040 x 36.50 x 36.50	2014-T6 AL
1			-011	FACE	.040 x 36.50 x 36.50	2014-T6 AL
	1	1	-007	CORE	.595 x 36.50 x 73.00	5052-0 AL .125-.0007-3.1 #/FT³ HONEYCOMB
	1	1	-006	FACE	.040 x 36.50 x 73.00	2014-T6 AL
	1	1	-005	FACE	.040 x 36.50 x 73.00	2014-T6 AL
	2	2	-004	STRIP	.20 x 5.00 x 36.50	GLASS LAMINATE - EPOXY
	2	2	-003	STRIP	.20 x 3.00 x 36.50	GLASS LAMINATE - EPOXY
			-019	SP-ALUM-10	SHEAR TEST PANEL ASSY	
			-010	DP-ALUM-10	DEVELOPMENT PANEL	
			-009	CP-ALUM-10	COMPRESSION TEST PANEL ASSY	
-019	-010	-009				

LIST OF MATERIAL

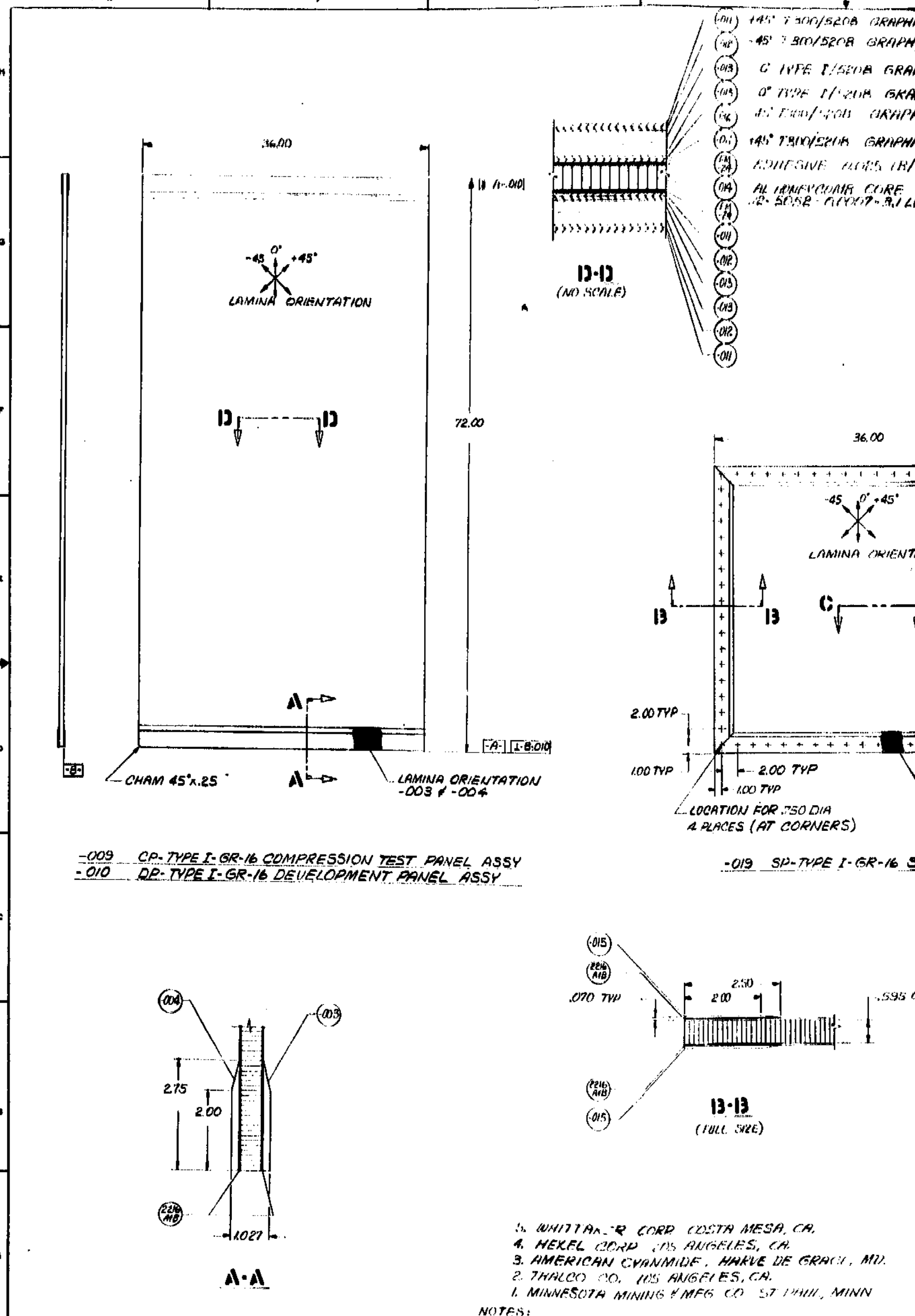
GRIDE 0435 4-10-4

MARTIN MARIETTA CORPORATION

ALUMINUM HONEYCOMB TEST PANELS

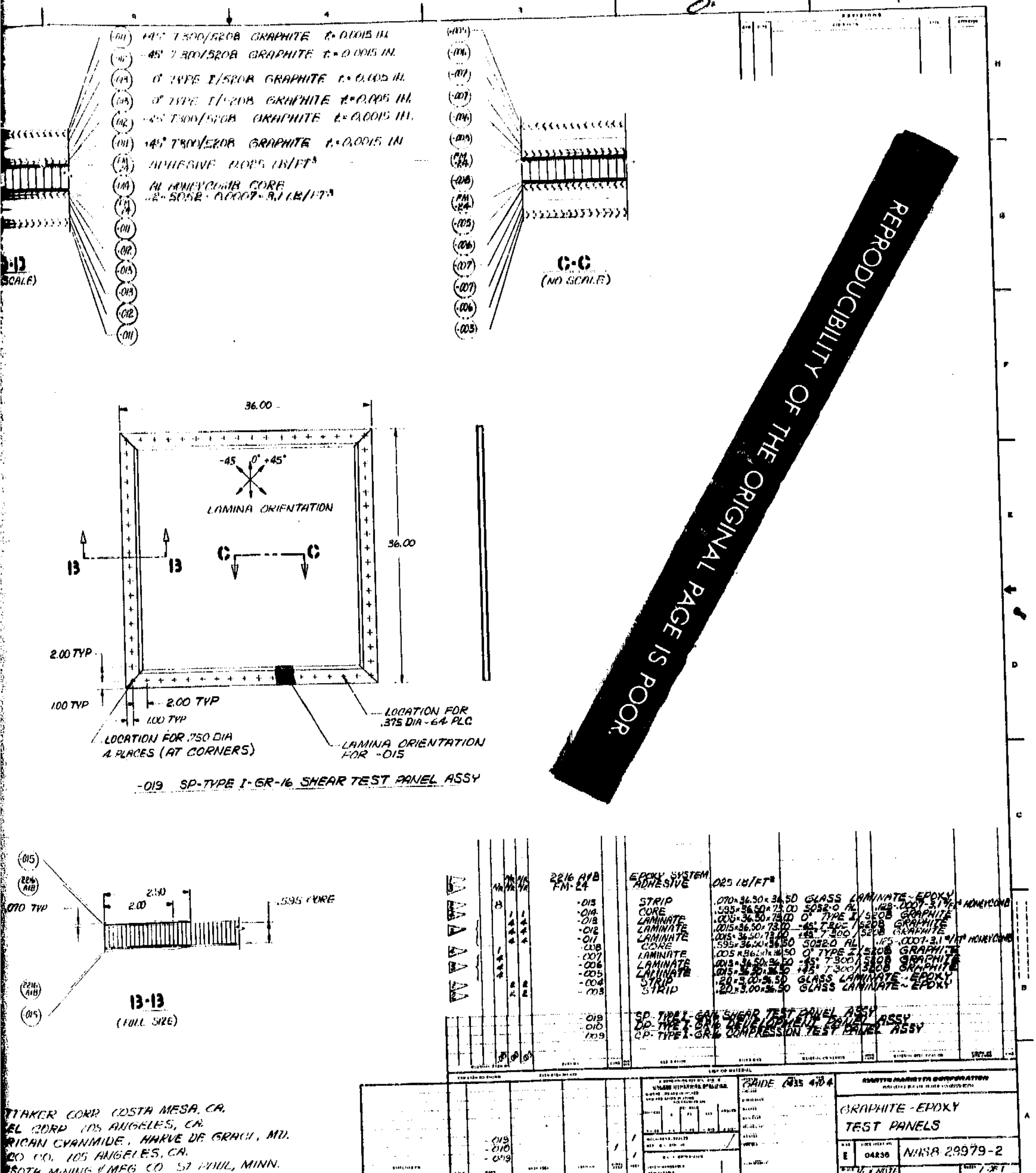
E 04836 NAS8-29979-3

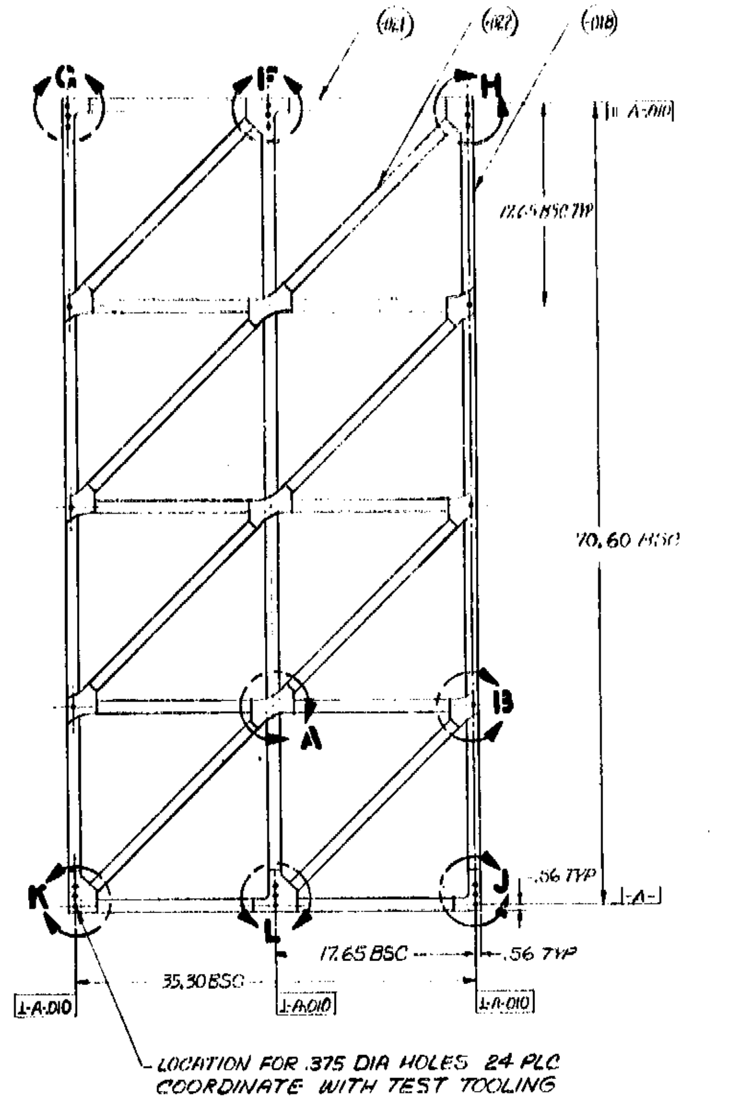
LOS ANGELES, CA.
... PRAIRIE DE CLARE, MD.
LOS ANGELES, CA.
... ST PAUL, MINN



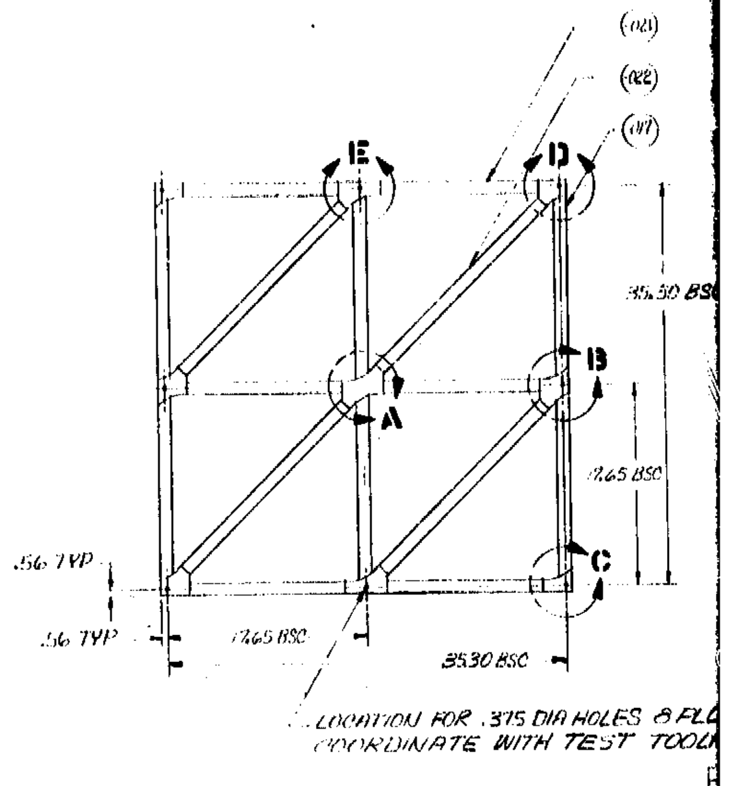
36.00
72.00
LAMINA ORIENTATION
-45 0° +45°
CHAM 45° x .25
LAMINA ORIENTATION -003 & -004
-009 CP-TYPE I-GR-16 COMPRESSION TEST PANEL ASSY
-010 DP-TYPE I-GR-16 DEVELOPMENT PANEL ASSY
D-D
(NO SCALE)
ADHESIVE
AL HONEYCOMB CORE
2.00 TYP
1.00 TYP
LOCATION FOR .750 DIA 4 PLACES (AT CORNERS)
-019 SP-TYPE I-GR-16
2.75
2.00
1.027
A-A
.070 TYP
2.50
2.00
B-B
(FULL SIZE)
5. WHITTAKER CORP COSTA MESA, CA.
4. HEXEL CORP LOS ANGELES, CA.
3. AMERICAN CYANMIDE, HARVE DE GRACE, MD.
2. THALCO CO. LOS ANGELES, CA.
1. MINNESOTA MINING & MFG CO ST PAUL, MINN
NOTES:

FOLDOUT FRAME





-009 CP-AL TRUSS COMPRESSION PANEL ASSY
-010 DP-AL TRUSS DEVELOPMENT PANEL ASSY



--019 SP-AL TRUSS SHEAR ASSY

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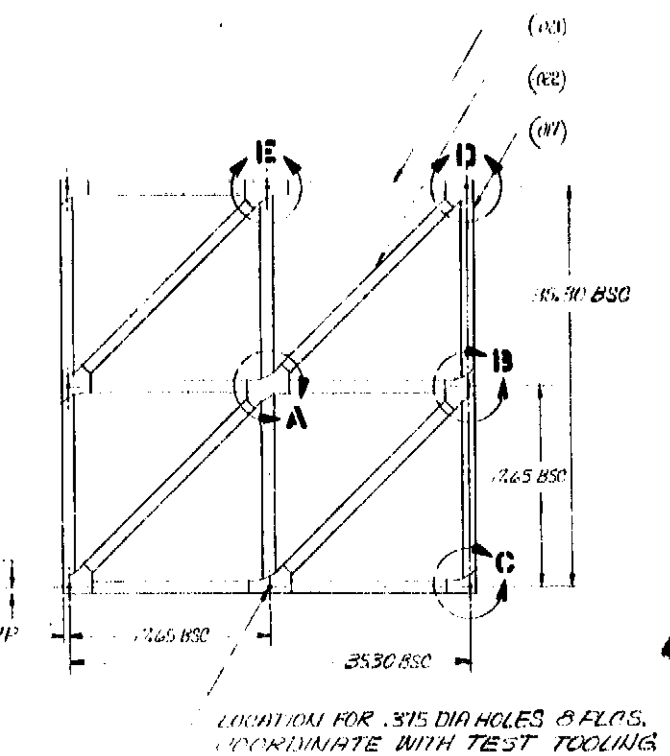


-019 SP-AL. TRUSS SHEAR ASSY

1	18	24	16	GR2251-6-2	RIVET	UNIVERSAL HD, BULBED CHERRYLOCK, 3/16 DIA	
	4	11	11	-022	TUBE-DIAGONAL	.50 × .02 × .450 × 24.00	2024-T3 AL ALLOY TUBE, H.T. TO -T81
	6	10	10	-021	TUBE-HORIZONTAL	.50 × .02 × .450 × 17.00	2024-T3 AL ALLOY TUBE, H.T. TO -T81
		9	9	-018	TUBE-VERTICAL	.50 × .02 × .450 × 72.50	2024-T3 AL ALLOY TUBE, H.T. TO -T81
	3			-017	TUBE-VERTICAL	.50 × .02 × .450 × 37.00	2024-T3 AL ALLOY TUBE, H.T. TO -T81
		2	2	-016	CAP-CORNER	.050 × 4.50 × 4.50	7075-T6 AL ALLOY
		2	2	-015	CAP-CORNER		
		2	2	-014	CAP-CORNER		
		2	2	-013	CAP-CORNER		
		2	2	-012	CAP-CORNER		
		2	2	-011	CAP-CORNER	.050 × 4.50 × 4.50	7075-T6 AL ALLOY
	4	12	12	-008	CAP-SIDE	.050 × 4.50 × 4.50	7075-T6 AL ALLOY
	4			-007	CAP-END		
	4			-006	CAP-CORNER		
	4			-005	CAP-CORNER		
				-004	CAP-CENTER		
	2	6	6	-003	CAP-CENTER	.050 × 4.50 × 4.50	7075-T6 AL ALLOY
				-019	SHEAR PANEL ASSY-TEST		
				-010	COMPRESSION PANEL-DEVELOPMENT		
				-009	COMPRESSION PANEL-TEST		
	-019	-010	-009				

HOLE SIZE FOR CHERRYLOCK IS .209/.205 DIA.
ORIENT ... WITH ... CHECK
... MAKE CORNERS

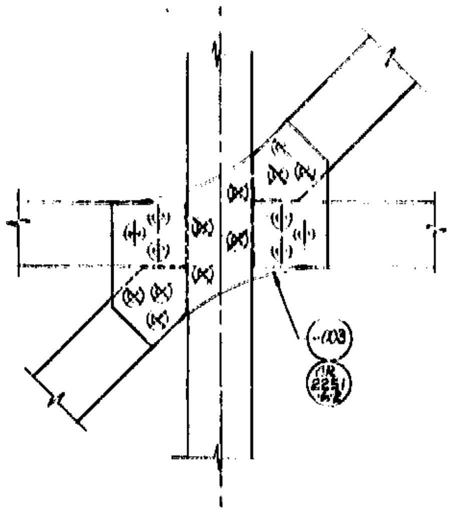
-019
-010
-009

CODE 2435 4764

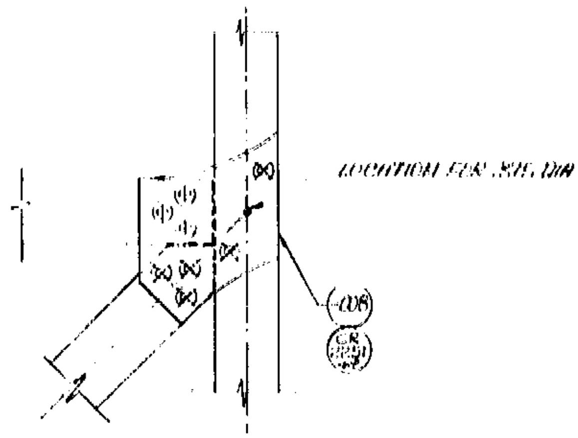
MARTIN MARIETTA CORPORATION

ALUMINUM TRUSS
TEST PANELS

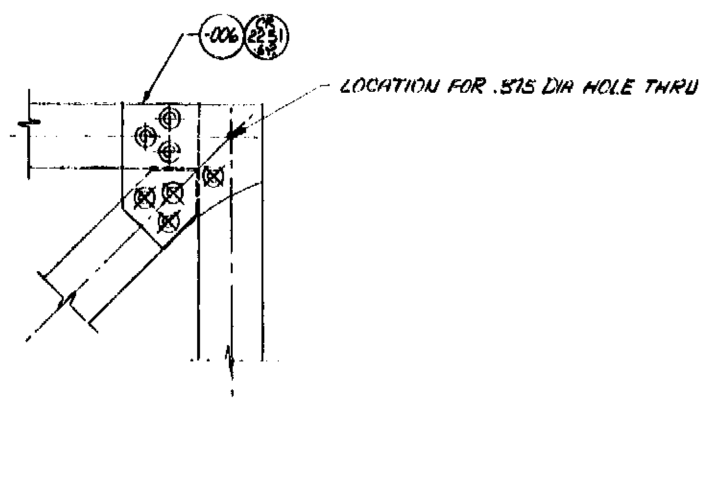
E 04236 NAS8-31970-1



DETAIL A



DETAIL B



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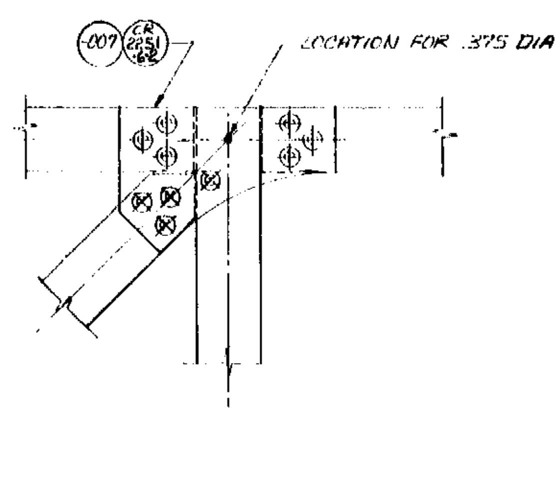
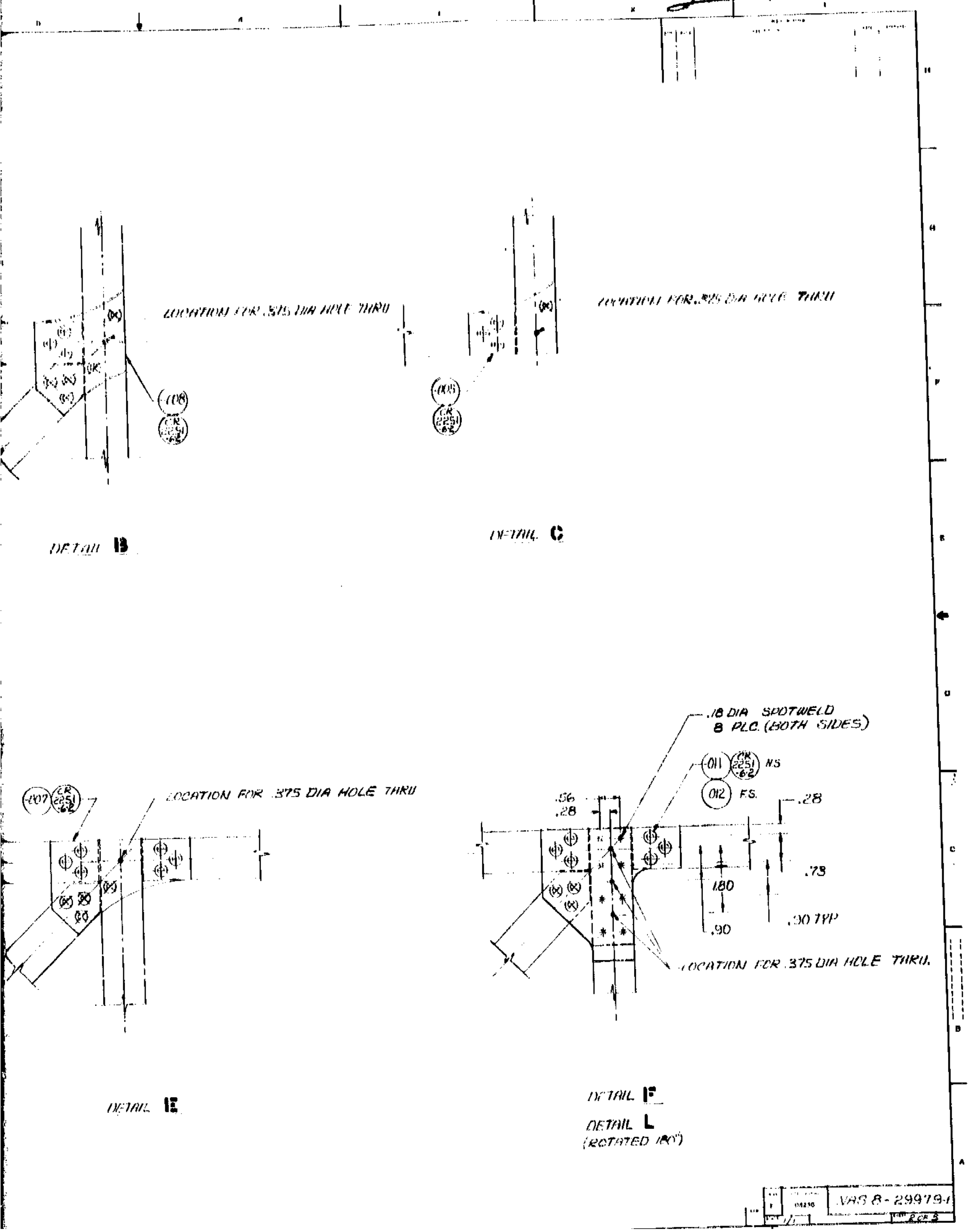
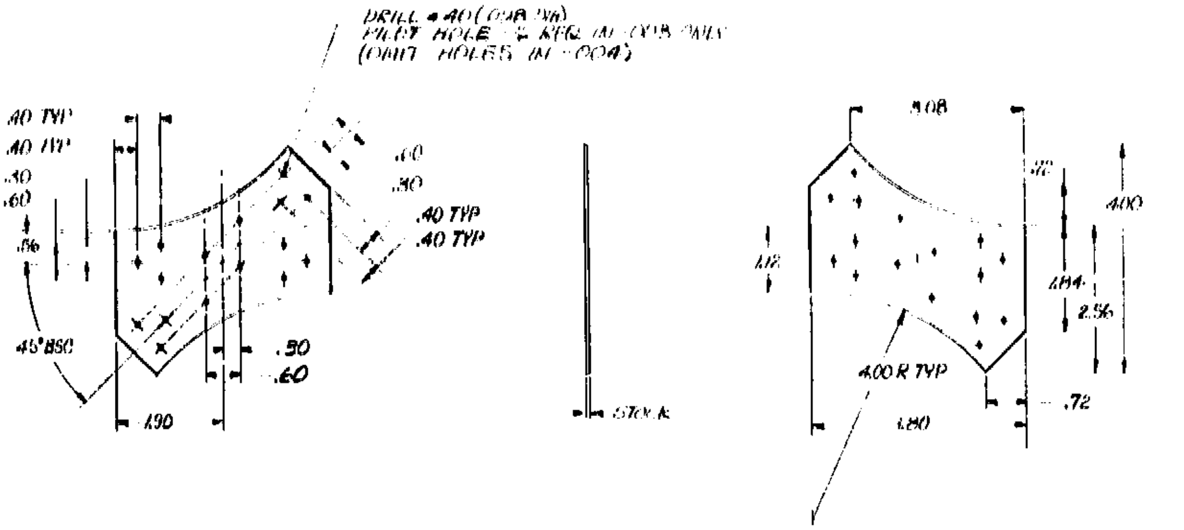


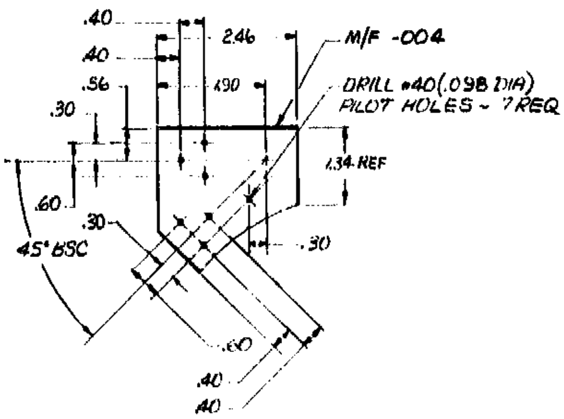
DETAIL E

FOLDOUT FRAME

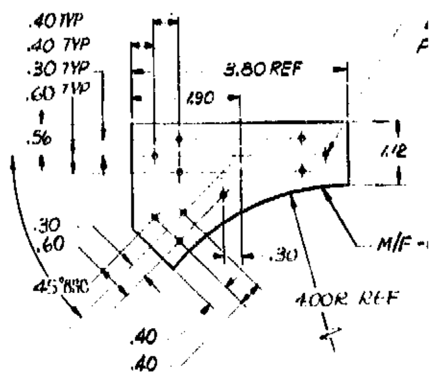




DETAIL -003
DETAIL -004

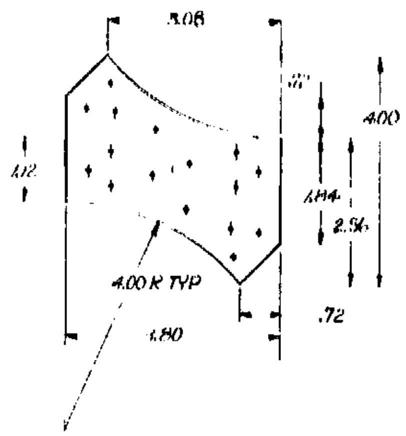


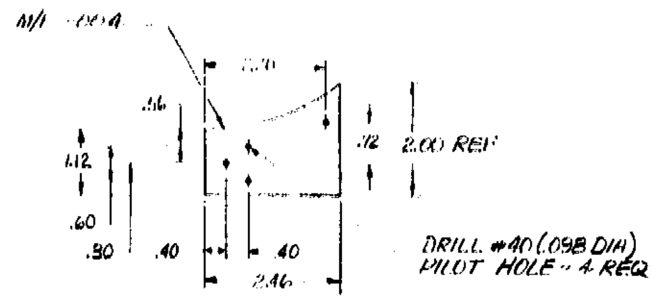
DETAIL -006



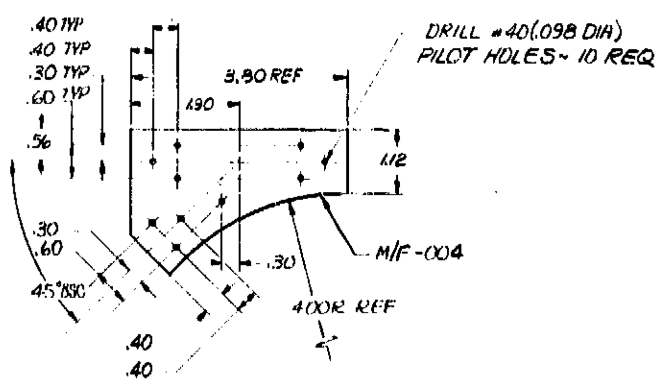
DETAIL -007

FOLDOUT FRAM





DETAIL -005



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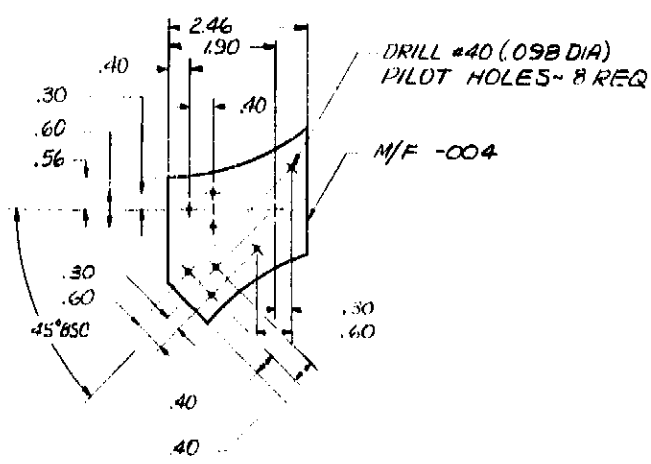

DETAIL -008

NAS8-29379-1

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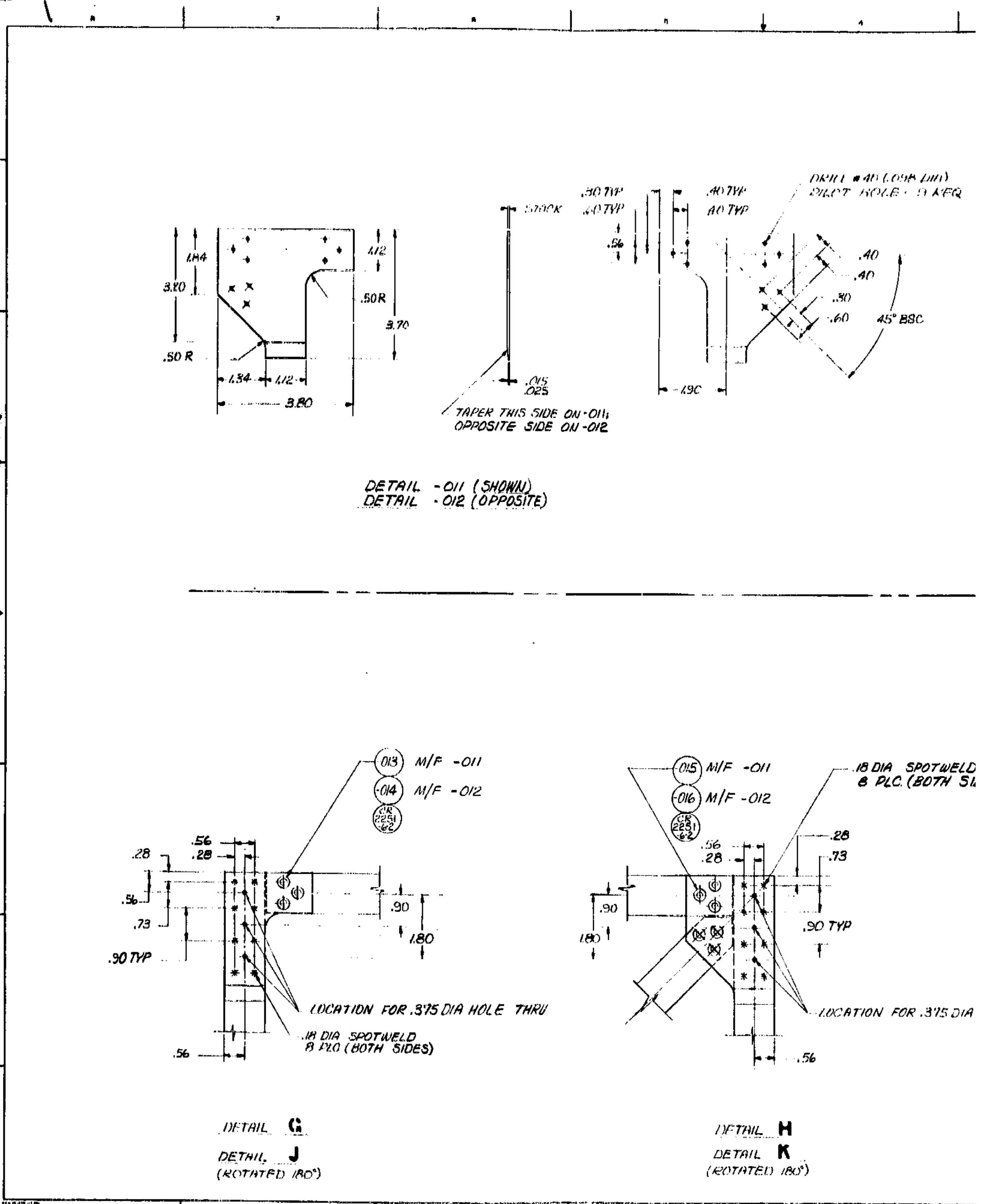
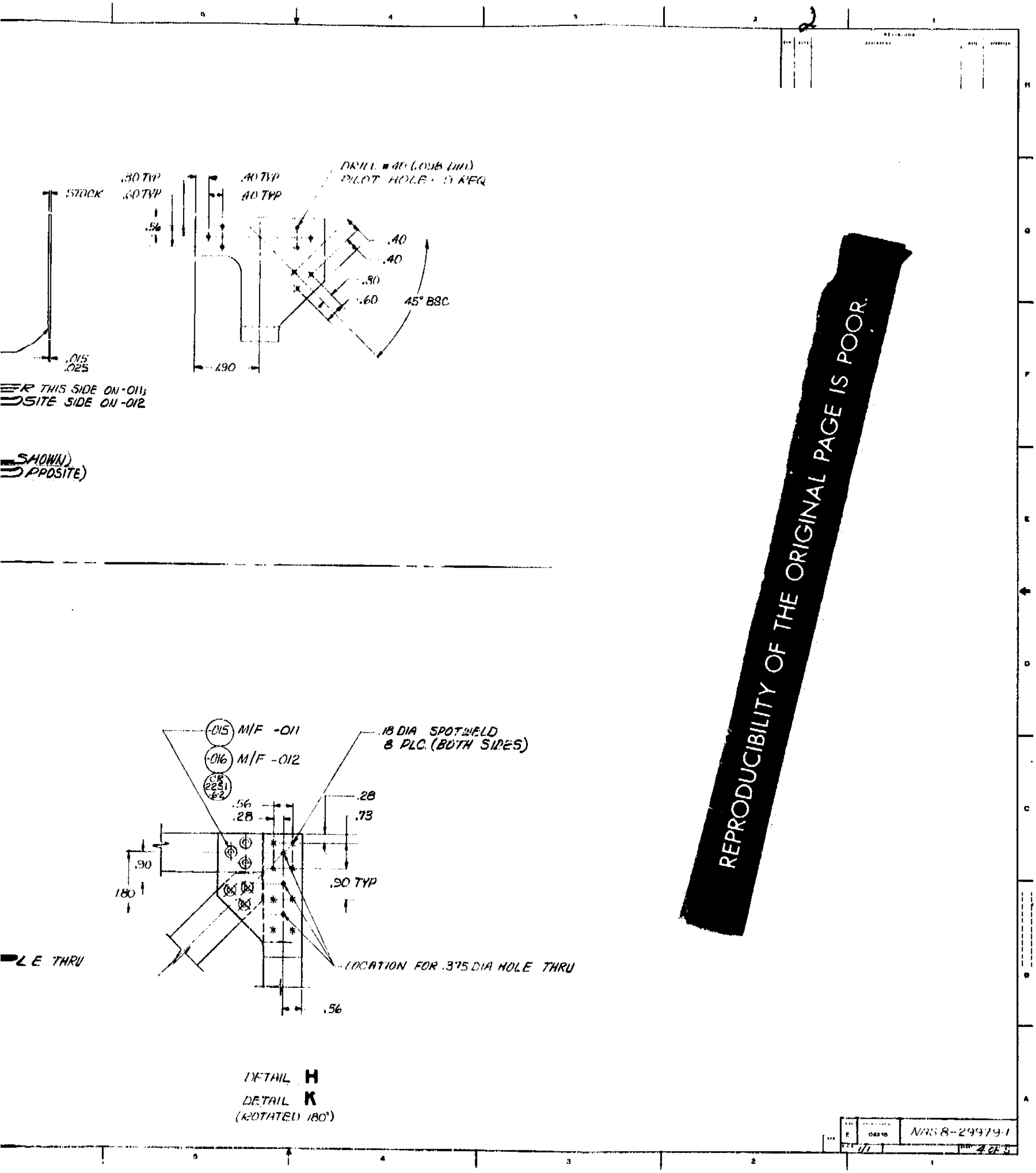
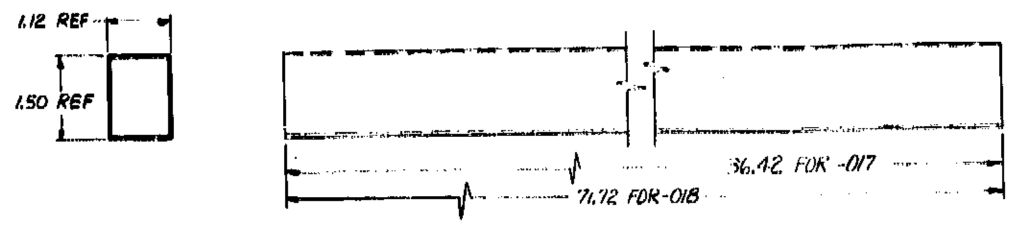
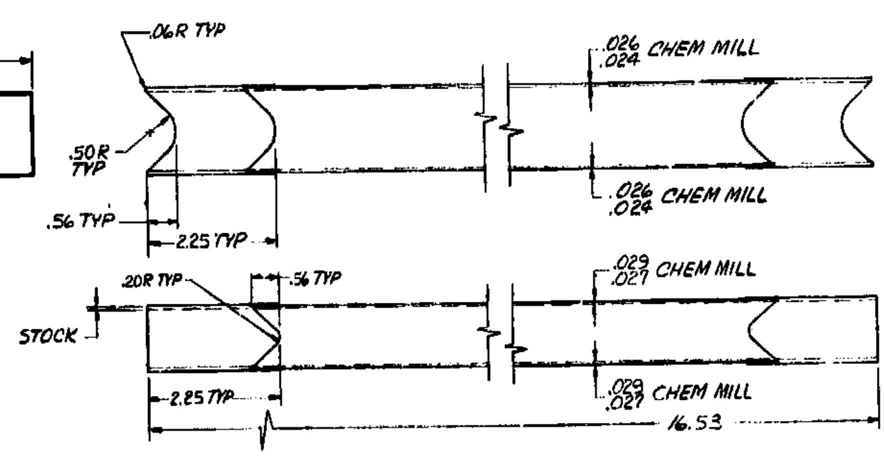


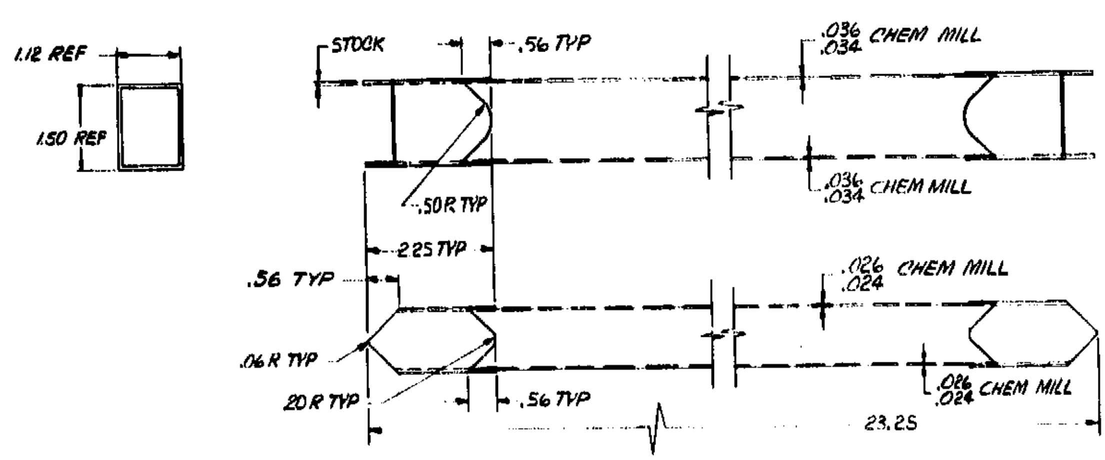

STOCK
.30 TYP
.60 TYP
.40 TYP
.40 TYP
.56
DRILL #40 (.098 DIA) PILOT HOLE - 5 REQ
.40
.40
.30
.60
45° BSC
.015
.025
.190
R THIS SIDE ON -011;
SITE SIDE ON -012
SHOWN)
PPOSITE)
-015 M/F -011
-016 M/F -012
.18 DIA SPOTWELD
8 PLC. (BOTH SIDES)
.56
.28
.28
.73
.90
180
.90 TYP
LE THRU
LOCATION FOR .375 DIA HOLE THRU
.56
DETAIL H
DETAIL K
(ROTATED 180°)
NAS 8-29979-1
4 OF 5



DETAIL -017
DETAIL -018



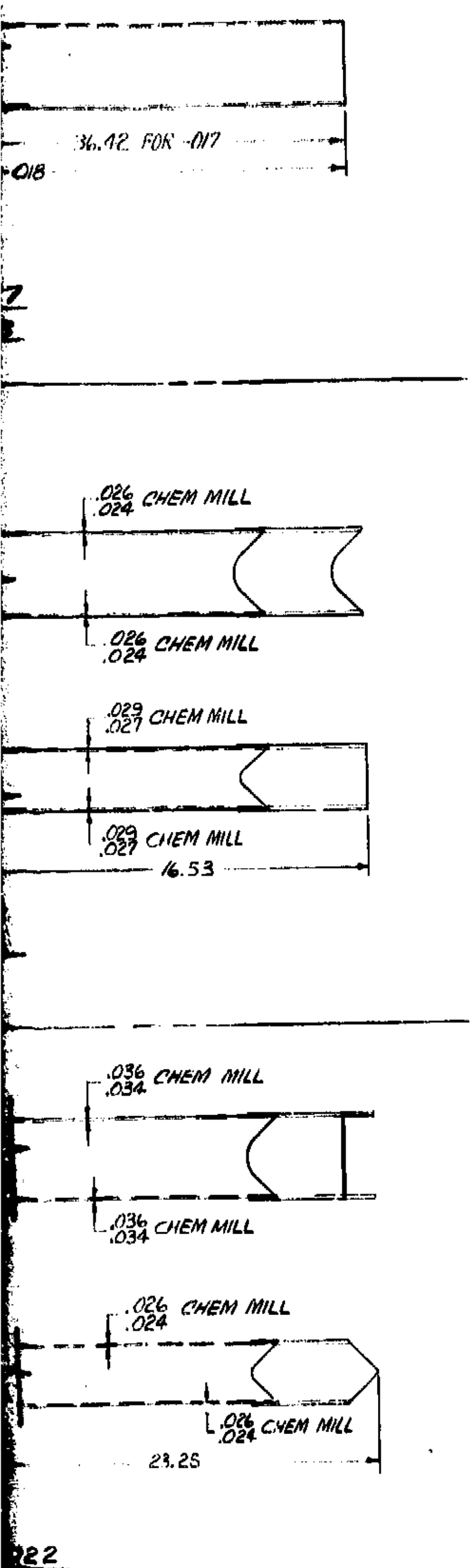
DETAIL -021



DETAIL -022

FOLDOUT FRAME

2



NAS 8-29979-1

APPENDIX B

MANUFACTURING PROCESSES

I. FABRICATION PLAN GRAPHITE/EPOXY HONEYCOMB SANDWICH PANELS

Faceskin Fabrication

1. Prepare layup tool for fabrication of faceskin
2. Cut graphite/epoxy prepreg details.
3. Layup six layers of graphite/epoxy
4. Apply vacuum bag system and evacuate
5. Place in autoclave, heat to 180°F in 30 min and hold for 15 min
6. Remove heated part from autoclave and compact with teflon paddle while hot
7. Place back in autoclave and cure per Narmco 5208 cure cycle
8. Remove cured faceskin from autoclave
9. Remove vacuum bag system and trim faceskin to desired dimensions
10. Repeat above steps for second faceskin

Honeycomb Sandwich Panel Fabrication

1. Lightly sand rough side of two graphite/epoxy faceskins
2. Clean with MEK solvent and seal in clean bag
3. Cut aluminum honeycomb core to size
4. Clean core pieces by degrease, alkaline clean, rinse, deoxidizer etch and rinse operation
5. Cut FM-24 adhesive film to required sizes
6. Cut Narmco Metlbond 6602 core splice adhesive to size
7. Layup faceskin, FM-24 adhesive, core and core splice, FM-24 adhesive, faceskin and 0.025" aluminum caul plate on layup tool
8. Apply vacuum bag system and evaluate
9. Cure in autoclave using FM-24 cure cycle
10. Remove cured part from autoclave
11. Remove vacuum bag system and trim cured panel to desired dimensions
12. Prepare fiberglass end or edge reinforcement details for bonding
13. Prepare panel end or edge regions for bonding
14. Place fiberglas reinforcement pieces and FM-24 adhesive film on sandwich panel
15. Place in holding tool
16. Cure in autoclave using FM-24 cure cycle
17. Remove from autoclave and trim to finish dimensions

II. FABRICATION PLAN ALUMINUM HONEYCOMB SANDWICH PANELS

Faceskin Fabrication

1. Mask one side of aluminum sheet to be chem milled
2. Attach masked aluminum to plywood sheet for support
3. Chemically mill to intermediate thickness to determine etch rate
4. Chem mill to desired thickness in steps rotating part after each step
5. Remove masking material from finished aluminum sheet
6. Store in sealed bag
7. Repeat above steps for second faceskin

Honeycomb Sandwich Panel Fabrication

Follow steps 3 through 17 of Table 1, Fabrication Plan, Graphite/Epoxy Sandwich Panels

III. FABRICATION PLAN ALUMINUM TRUSS PANELS

A. Truss tube components
   1. Cut aluminum tube components to desired lengths
   2. Mask and trim appropriate areas prior to chem mill
   3. Chemically mill to desired dimensions
   4. Trim components to final dimensions

B. Joint doubler plates
   1. Cut doubler plates to desired size
   2. Drill guide holes in plates to be used on top surface of panel

C. Fiberglass meteoroid protection sheets
   1. Prepare layup tool for fabrication of fiberglass sheets
   2. Cut single style 112 prepreg cloth sheet to size
   3. Layup fiberglass sheet and vacuum bag system and evacuate
   4. Cure in autoclave using Narmco 5208 cure cycle
   5. Repeat above steps for second sheet

D. Panel Assembly
   1. Place truss tube components and joint double plates in assembly tool
   2. Drill holes using upper doubler plates with predrilled holes as templete
   3. Attach using bulbed cherry lock rivets
   4. Spotweld end doubler plates of compression panel at appropriate places
   5. Remove panel from holding fixture
   6. Heat treat in oven to obtain -T81 temper